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Report

FINAL

REMEDIAL INVESTIGATION REPORT SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY

JANUARY 1995**Prepared By:**

**Camp Dresser & McKee Inc.
233 South Wacker Drive
Suite 450
Chicago, Illinois 60606**

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Section One



Section 1

Introduction

The primary purpose of this Remedial Investigation (RI) Report is to present and interpret the results from the Phase II field activities for the Southeast Rockford Groundwater Contamination Study conducted from January 1993 through January 1994.

The Phase II field activities were designed to achieve the following objectives:

- Review historical information on potential source areas identified prior to Phase II;
- Provide preliminary screening information for the identified source areas;
- Define the extent of groundwater contamination within the Phase II study area;
- Evaluate contaminant migration pathways between source areas and the study area;
- Evaluate the potential for non-aqueous phase liquids in the subsurface;
- Monitor volatile organic vapors in residential basements located in areas of elevated contaminant concentrations in shallow groundwater;
- Evaluate the risk to residents with drinking water wells within the Operable Unit study area; and
- Gather data for a groundwater model to be used to assist with plume definition, source area location, and evaluation of remedial alternatives.

This investigation was not designed to identify new source areas.

Phase II field activities included a soil gas survey of twelve potential source areas, soil boring installation and sampling, monitoring well installation and sampling, residential well sampling, residential air sampling and Source Area 7 test pit soil and ambient air sampling. During the Phase II field activities, 212 soil gas points were sampled, 44 monitoring wells were installed, 55 subsurface soil borings were drilled, 116 subsurface and 10 surface soil samples were collected, 165 groundwater samples were collected from monitoring wells, 24 groundwater samples were collected from residential wells, 20 residential air samples were collected, and two test pits were excavated in the study area.

An additional objective of this RI Report is to assimilate the data collected by IEPA/CDM from the Operable Unit, Phase I and Phase II studies, USGS, and work conducted by individual facilities throughout the study area into one report to be used to support the Feasibility Study (FS) and Record of Decision (ROD).

1.1 Study Area Description

The Southeast Rockford Groundwater Contamination study area is located in southeast Rockford in Winnebago County, and covers approximately 10 square miles. The study area is bounded by Broadway to the north, Sandy Hollow Road to the south, Mulford Road in the eastern portion of Section 4 to the east, and the Rock River to the west. The workplan describes the eastern boundary as Wendy Lane, however this was adjusted to Mulford Lane to provide a main roadway for the eastern boundary.

The study area is predominantly an urban and suburban residential area, which includes scattered industrial, agricultural, retail and commercial operations. A small industrial park is located in the central portion of the study area in the vicinity of Laude Drive and 22nd Street. Other industrial areas are situated in the vicinity of Harrison Avenue and Alpine Road, Sandy Hollow Road and Alpine Road, near the Rock River in the northwest and elsewhere in the study area. Agricultural areas are present in the southeastern portion of the study area, as well as areas to the east and south of the study area. A larger scale map of the study area is included as Plate 1-1 at the back of this volume. This map may be used throughout the report to locate pertinent site features not detailed on smaller scale maps.

The study area is predominantly flat-lying and slopes gently westward towards the Rock River, but locally contains low-relief hilly areas. Maximum topographic relief across the study area is approximately 160 feet. A small concrete-lined drainage ditch runs across the western portion of the study area and discharges to the Rock River in the southwestern corner. A review of 117 IDPH well construction reports established that the majority of the residential wells in the western part of the study area were screened in the 40-feet to 70-feet range in a sand and gravel aquifer. However, few residential wells are present in the portion of the study area east of 24th Street. Although deeper residential wells exist in the study area, no systematic distribution of the deeper wells is evident. A review of data from City of Rockford municipal wells established the local stratigraphy in deeper portions of the subsurface, and showed the penetration of low contaminant concentration to those depths.

The study area has been expanded in all directions from the boundaries which were used to score the site for inclusion on the United States Environmental Protection Agency's (USEPA's) National Priorities List (NPL), because sampling results have indicated that the plume of contaminated groundwater extends beyond the original NPL site boundaries. The original NPL boundaries were 8th Street to the west, Sawyer Road to the south, 21st Street to the east, and Harrison Avenue to the north (Figure 1-1).

The stratigraphy of the study area consists of bedrock with locally significant subsurface relief that is overlain by unconsolidated glacial sediments of variable thickness. The uppermost bedrock unit is generally dolomite, which forms a subsurface valley greater than 200 feet deep in the western part of the study area. Glacial sediments are thickest within this bedrock valley and thinnest on the valley flanks. The glacial sediments and the bedrock constitute two hydraulically-connected aquifers; no areally extensive aquitards have been identified between the unconsolidated deposits and the dolomite.

1.2 Study Area History

Groundwater contamination by volatile organic compounds (VOCs) was initially discovered by the Rockford Water Utility (RWU) in 1981. Four municipal wells in Southeast Rockford were taken out of service in December 1981 due to the contamination. In 1982, the city discovered that additional wells were contaminated and subsequently closed down these wells. Within the study area, municipal Unit Well 35, located near Ken Rock Playground (Bildahl Street and Reed Avenue), was found to be contaminated during a routine sampling of the well in 1984; the well

SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY
NPL SITE BOUNDARY

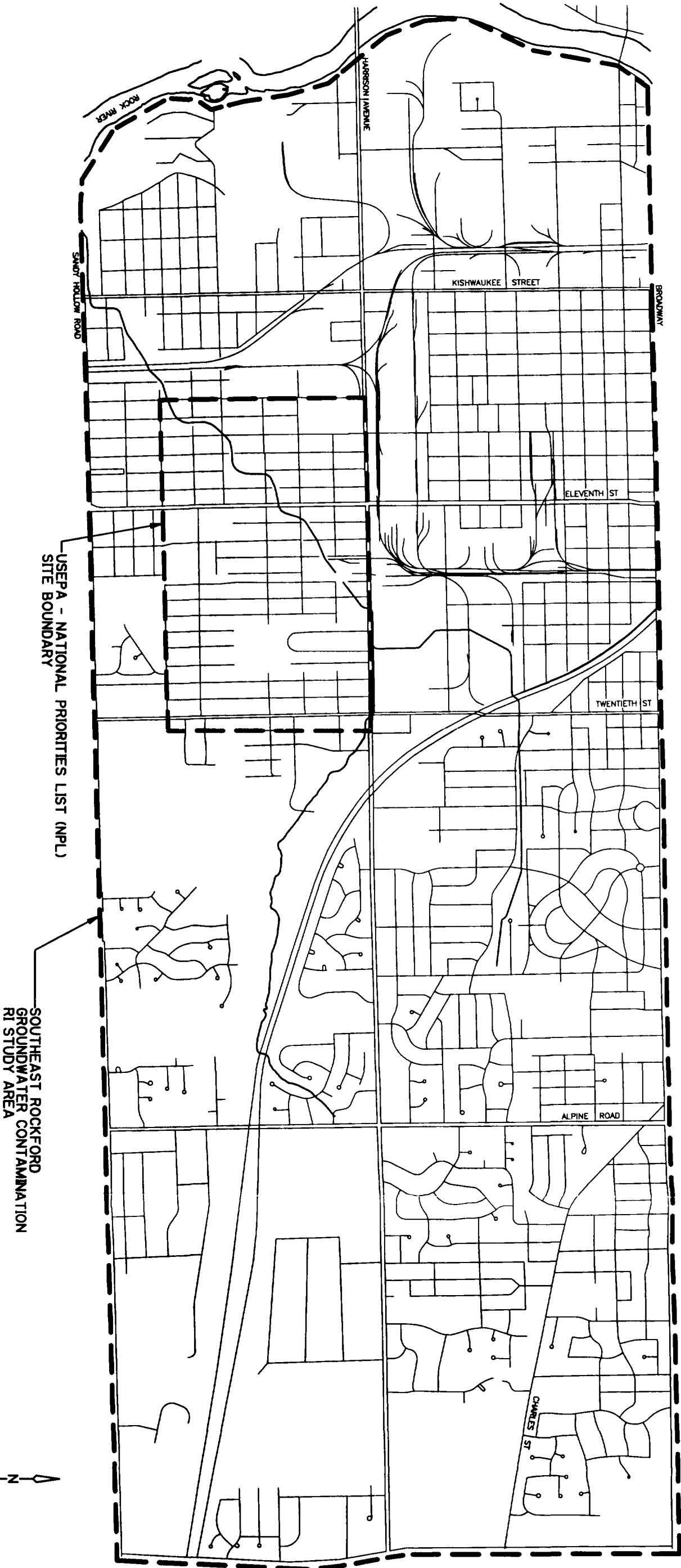


Figure No. 1-1

was tested for 33 priority pollutants and several VOCs were detected. Because contaminants were present at levels above the Safe Drinking Water Act Maximum Contaminant Level (MCL), the well was taken out of service in 1985. During the "operable unit remedial action" conducted by USEPA (July 1991 to November 1991) a granular activated carbon treatment system was installed at Unit Well 35. The well is now pumped periodically based on service demand.

IEPA discovered that VOCs were present in Southeast Rockford's water in 1984 as a result of a report that plating wastes were being illegally disposed of in a well located at 2613 South 11th Street. In October 1984, IDPH initiated an investigation that involved sampling 49 wells in the vicinity of this well. While the investigation did not find significant levels of contaminants commonly associated with plating wastes, it did report high levels of chlorinated solvents, which were also detected in the City of Rockford's municipal well. IDPH conducted four separate sampling investigations involving residential wells in the Southeast Rockford area: 49 samples were collected in 1984, 43 samples in 1985, 17 in 1988, and 267 in 1989. For the most part, sample locations varied during the separate sampling investigations; however, in some cases, wells were sampled more than once.

In 1986, the Illinois State Water Survey (ISWS) completed a project which involved a regional characterization of groundwater quality in Rockford. The study indicated that groundwater samples from public and private wells in the Southeast Rockford area contained significant concentrations of VOCs. Seven private well sites sampled in the Southeast Rockford area as part of the study contained greater than 10 µg/l total VOCs; five of those seven contained greater than 100 µg/l total VOCs. One of the private wells containing greater than 100 µg/l total VOCs was located near the Rock River (Wehrmann, 1988).

As a result of sampling events by state and federal agencies, the Southeast Rockford site was proposed for inclusion on the NPL in June 1988 and was added to the NPL in March 1989 as a state-lead, federally-funded Superfund site. Throughout 1989, the USEPA Technical Assistance Team (TAT) sampled 112 residential wells in the Southeast Rockford area and tested for the following abbreviated list of VOCs:

- Trichloroethene
- cis-1,2-Dichloroethene
- 1,2-Dichloroethane
- 1,1,1-Trichloroethane
- trans-1,2-Dichloroethene, and
- 1,1-Dichloroethane

In August 1989, the USEPA initiated a time critical removal action under which bottled water was offered as a temporary measure to residents whose well water analysis results revealed VOC levels greater than or equal to 25 percent of the Removal Action Level (RAL). In mid-December 1989, these residences were equipped with carbon filters as an intermediate solution to the problem. USEPA ultimately extended water mains and provided hookups to city water to 283 residences between June and November 1990.

During June 1990, Camp Dresser & McKee (CDM), under the direction of IEPA, conducted a groundwater sampling investigation of 117 private wells in Southeast Rockford as part of the Operable Unit Remedial Investigation. The objective of this sampling was to see if any homes

had wells with levels of VOCs below the time critical removal action cutoff, but above MCLs. The IEPA sampling revealed an additional 243 homes that needed to be connected to the City of Rockford's municipal water supply system.

The Proposed Plan for this Operable Unit was released to the public in March 1991 and included the connection of the affected homes to the municipal supply and the construction of a granular activated carbon (GAC) treatment facility for municipal Unit Well 35. The Record of Decision (ROD) was signed in June 1991.

The Operable Unit was established under the removal program in order to complete construction during 1991. By November 1991, 264 homes were connected to city water. By November 1992, the GAC unit was completely operational and available to assure sufficient service capacity for the area.

From May to October of 1991, CDM and its subcontractors, under the direction of IEPA, conducted the Phase I Remedial Investigation. In Phase I, the study area was expanded from the original NPL site boundaries to an area of approximately 5 square miles. The Phase I area was bounded on the north by Harrison Avenue, on the south by Sandy Hollow Road, Wendy Lane to the east and the Rock River to the west. Phase I activities included a 225-point soil gas survey, installation of 33 monitoring wells at 11 locations, hydraulic conductivity testing, sampling and analysis of the 33 Phase I wells, 19 Illinois State Water Survey (ISWS) wells and 16 industrial wells, and subsurface soil sampling during drilling. The Phase I study was designed to define the nature and distribution of groundwater contamination, define local geology and hydrogeology, and to gain preliminary information on potential contaminant source areas.

The results of the Phase I investigation indicated two areas of groundwater contamination of volatile organic compounds, including one area located near the industrial facility southeast of the intersection of Harrison Avenue and Alpine Road, and a larger area near and down-gradient (west-northwest) from well nest MW106 (see Figure 3-11). Near the downgradient extent of this plume, several plumes, possibly related in part to the larger plume, are located west and southwest of MW20.

Based on elevated VOC concentrations in soil gas or groundwater, eight (8) potential source areas were also identified during the Phase I Investigation, as follows: 1) upgradient from well nest MW106 (Area 7); 2) upgradient from well nest MW101 (Areas 5 and 6); 3) at the industrial facility southeast of Harrison Avenue and Alpine Road (Area 8); and 4) several discrete locations in industrial areas in the western part of the study area (Areas 1 through 4). At the conclusion of the Phase I field activities a Technical Memorandum was prepared.

Subsequent to Phase I, CDM examined information on industrial operations and defined additional potential source areas that were proposed for investigation during Phase II. These areas were identified as Areas 9 through 14 (see Figure 4-1). The information examined included IEPA files from the Rockford office, and information on facility practices provided to the USEPA by industrial enterprises, under an ongoing enforcement action.

In March 1992, USEPA and IEPA conducted a preliminary geophysical survey of Potential Source Areas 6 and 7 that were identified in the Phase I Technical Memorandum. This survey was prompted by reports of illegal dumping in Area 7 and the results of groundwater samples collected during Phase I from MW106, 108 and 109.

Based on the preliminary results of the March 1992 survey, a more detailed investigation was performed by CDM and USEPA in May 1992 in Area 7. The investigation included a terrain conductivity survey, a ground-penetrating radar survey and a soil gas survey (see Figure 4-3). Survey results indicated the presence of buried magnetic anomalies and VOCs in the soil gas, primarily in the area of Ekberg Park (in Area 7).

The Phase II scoping activities began in the summer of 1992. The objectives of Phase II included: 1) filling data gaps identified in Phase I; 2) providing sufficient information on potential source areas to allow an evaluation of need for future work; 3) gathering sufficient information to expand the groundwater model; and 4) gathering sufficient information to support a risk assessment and feasibility study.

The Phase II field activities were conducted from January 1993 to January 1994.

1.3 Organization of the Report

Section 2 of this report describes the analytical and field protocol used during the field activities. The results of the hydrogeologic investigation are discussed in Section 3. Section 4 details the results of the contaminant investigation. The groundwater modeling procedures, assumptions and results are presented in Section 5. Section 6 contains the risk assessment for residential wells. Conclusions and recommendations are detailed in Section 7 and references are provided in Section 8.

2

Section
Two

Section 2 Field Investigation Methods and Procedures

2.1 Analytical Procedures

As detailed in the approved Quality Assurance Project Plan (March, 1993) for the Southeast Rockford Phase II Remedial Investigation, the analytical procedures for the CLP Laboratory are specified in the current USEPA CLP SOW OLM01.0 (8/91) for RAS low-medium concentration organic analyses, in the current CLP SOW ILM02.0 (9/91) for RAS low-medium concentration inorganic analysis, in the current CLP SOW (9/88) for high-concentration organic analyses and in the current CLP SOW IHC01.1 for high-concentration inorganic analyses. The analytical procedures for SAS CLP Laboratory analyses are specified in the SAS Client Request Forms (provided in the Phase II QAPP). The analytical method (SW846 8010) used by Analytical Laboratory Services Inc. of Rockford, Illinois for the screening level volatile organic analysis is provided in the QAPP. The method for the on-site analysis of volatile organics in soil gas was conducted using a field gas chromatograph in accordance with the method provided in Appendix B of the Phase I QAPP (February, 1991).

2.2 Field Quality Control Procedures

Field quality control procedure for groundwater consisted of the collection and analysis of trip blanks, field blanks, field duplicates and a sample of the water used for drilling. Field duplicates were collected and analyzed for soil samples. Both residential and test pit air samples had field duplicates and field blanks collected at the time of sampling. Trip blanks (analyzed for volatile organics only) are used to determine whether sample contamination had occurred from sample packaging or shipping. Field blanks serve to reveal possible sample contamination derived from sampling procedures, packaging, or shipping. Field duplicates help to assess the reproducibility of the sampling process and how well the sample represents the environment.

Trip Blanks

The liquid trip blanks were prepared by the IEPA laboratory with deionized water and were preserved with hydrochloric acid to a pH <2. The trip blanks were transported to the field and shipped, unopened, with the investigative groundwater samples to the CLP laboratory. Trip blanks are used to check for possible bottle contamination or contamination resulting from packaging and shipping. They were submitted for VOC groundwater samples only, at a frequency of one per cooler as specified in the Sampling and Analysis Plan (SAP; CDM - April, 1993).

Field Blanks

Field blanks are used to assess whether contamination is introduced to liquid samples by sampling techniques, equipment, ambient field conditions, sample handling, packaging, or shipping.

Field blanks were to be collected at a frequency of one blank per 10 investigative samples for groundwater and air analyses. This frequency was met for all parameters except low detection level analysis for volatile organics in groundwater and air samples from residential basements. A total of 120 investigative groundwater samples were collected with only 11 associated field blanks. One field blank was inadvertently omitted. Forty investigative air samples were collected from residential basements. Only 2 field blanks were collected due to a limitation on the number of sample canisters. Groundwater field blanks were prepared using deionized water supplied in 20-liter plastic carboys by VWR Scientific. Field blanks were collected for the sample parameters and were filtered and/or preserved in the same manner as the samples.

Decontamination Drilling Water Sample

One sample was collected of the water used for drilling water. This sample is from the Rockford municipal water supply. The decontamination water was also taken from the Rockford municipal water supply, but at a different location. The drilling water likely reflects the composition of the water used for decontamination. The cleaning and initial rinsing of sampling instruments was performed using tap water from the Ken-Rock Community Center near the location of the field trailer. The final rinse of all instruments, except for the sampling pumps, was performed using deionized water; tap water was the final rinse for the interior of the sampling pumps.

Field Duplicates

To ascertain the reproductibility of data, field duplicates were collected and analyzed for soil, air, and groundwater samples. Duplicate samples were collected by alternately filling sample containers for each analytical fraction for the sample and then the duplicate. The sample and duplicate were preserved and handled in a like manner. Field duplicates were to be collected at a frequency of at least 1 duplicate for every 10 investigative samples.

This frequency of duplicate collection and analysis were met in most cases. Test pit samples (8 investigative: 1 duplicate), subsurface soil samples for metals/cyanide (91 investigative: 9 duplicates), groundwater samples for volatile, semivolatile, pesticide/PCBs, and metals/cyanide samples (25 investigative: 4 duplicates), residential well samples volatile organics analysis (120 investigative: 12 duplicates), residential well samples (24 investigative: 2 duplicates) groundwater samples for general water quality analyses (45 investigative: 7 duplicates) and test pit air samples (18 investigative: 2 duplicates) all met the collection and analysis frequency criteria of 1 field duplicate for every 10 investigative samples.

The only two sample media and laboratory parameters that did not meet the duplicate frequency criteria were residential air samples (40 investigative: 1 duplicate) and subsurface soil samples

analyzed for volatile and semivolatile organics and pesticide/PCBs (116 investigative: 10 duplicates). The lack of duplicates for residential air was due to a shortage of sample apparatus shipped from the CLP lab and the shortage for the subsurface soils was due to poor recoveries during sampling. Even though duplicate frequencies were not met for the above subsurface soil parameters, the frequency is slightly below the required 10 percent and should not impact the quality of the data. Duplicate results for all sample matrices and laboratory parameters are discussed in Appendix E.

Sample Handling and Chain-of-Custody Procedures

Details of the sample handling and chain-of-custody procedures that were followed are outlined in the Final SAP (CDM - April, 1993), and only a general description is provided here. After the analytical samples were collected and preserved as appropriate, they were placed in ice-bearing coolers for the entire time that they remained in CDM's custody. The sample paperwork and sample packaging were done in the CDM field trailer. Sample Traffic Report/Chain of Custody Records were completed and sample tags were affixed to sample containers, which were then placed in coolers with bags of ice and vermiculite packing material. Packing tape was used to seal the coolers and custody seals were secured on the outside with clear tape. Sample coolers were shipped by overnight carrier to the assigned CLP or SAS laboratory. The fast turnaround screening level samples were hand delivered to ALS Laboratory in Rockford, in the provided coolers, each day that the samples were collected.

2.3 Soil Gas Survey

Introduction

From January 25, 1993 through February 17, 1993, CDM performed the Phase II soil gas survey at the Southeast Rockford Groundwater Contamination Study Area (Figure 4-1). The scope of the survey was to further delineate source contamination areas found in the Phase I investigation of the study area, and investigate possible new source areas based on other information gathered after Phase I, including aerial photographs, site visits, previous IEPA or USEPA studies, and information regarding industrial activities in the study area. To complete this scope of work, CDM contracted Tracer Research Corporation (TRC) of Tucson, Arizona to advance a total of 212 soil gas probes in twelve separate areas in the study area. Soil gas samples were collected from a depth of 5 feet, unless subsurface conditions impaired the advancement of the soil gas probe. In these cases, the sample would be collected at a shallower depth (3.5-4 ft.). Soil gas samples were analyzed in the field by use of a mobile gas chromatograph. All soil gas samples were analyzed for tetrachloroethene (PCE), 1,1,1-trichloroethane (TCA), and trichloroethylene (TCE). These compounds were chosen for analysis because they are the most prevalent compounds in the groundwater based on previous studies. Additional information regarding soil gas sampling parameters and procedures can be found in the Southeast Rockford Groundwater Contamination Phase 1 Final Quality Assurance Project Plan and Final Sampling and Analysis Plan dated February 1991.

Field Equipment Used

The field vehicle used by TRC to advance the soil gas probes and analyze the soil gas samples was a one-ton Ford van. The vehicle was divided into two main parts, the probe advancement/gas collection portion of the vehicle, located in the rear, and the analytical portion located inside of the vehicle. The vehicle was equipped with a hydraulic system activated by a hydraulic pump powered by the vehicle's engine. This hydraulic system makes possible the use of the large hydraulic ram used to advance soil gas probes into the subsurface. In the event that the hydraulic ram could not push the probe into the ground, a hydraulic falling head hammer (jack hammer) was used to advance the probe. When a hard surface such as asphalt or concrete was encountered, a Kango roto-hammer was used to drill a 1-1/2 inch diameter through which to advance the probe. A vacuum pump located in the vehicle was used to purge the soil gas sample from the probe.

To analyze the collected soil gas samples on-site, the vehicle was equipped with one Hewlett Packard model 5890 series II gas chromatograph, and two Hewlett Packard computing integrators. To supply the additional electric needed by the equipment, the vehicle used two gasoline-powered generators installed inside the vehicle. Exhaust gases from the generators were vented to the outside thus avoiding sample contamination from fumes. A crew of two people performed the soil gas survey, consisting of a chemist in charge of the analytical portion of the vehicle, and a sample technician to advance the probes and collect the soil gas samples.

Field Methods Used

Soil gas samples were collected using 7-foot long by 3/4-inch diameter steel pipe probes. Before advancing the probe with the hydraulic ram, an aluminum point was attached to the end of the probe. The point was temporary and remained in the ground upon removal of the probe. With the point attached, the sample technician placed the probe into the hydraulic jaws of the ram. The jaws held the probe while the ram advanced the probe to approximately 5 feet. The technician pushes the probe to 5 feet in depth. When the desired depth was attained the technician slowly raise the probe approximately three inches. This procedure removed the temporary point from the end of the probe, and created a small annular space for soil gas to collect. Once advancement of the probe was complete the technician attached a steel reducer to the top of the probe. The steel reducer has a barbed nipple at the end which allows a silicone hose to be connected to the probe. The silicone hose was then connected to the vacuum in the TRC vehicle. Upon activating the vacuum, the technician purged 3 to 5 volumes of gas from the probe thus removing any standing ambient air present. The length of time this procedure requires is dependent on the type of subsurface material the probe was pushed into. Tight clayey, very silty, or saturated materials require more time to purge than loose sandy or gravelly materials. After the technician completed purging the ambient air from the probe, a 10 ml glass syringe was inserted into the silicone tube. A soil gas sample was the drawn from the probe with the syringe, removed from the tube, and capped for analysis. After the sample was collected, the syringe was transferred to the chemist, where it was labeled, and put aside for analysis.

After the chemist determined that enough sample has been drawn from the probe, the technician removed the probe from the ground with the aid of the hydraulic ram. Once the probe was removed, granulated bentonite was used to backfill the hole.

In areas that the sampling vehicle could not access, the sample probes were advanced by hand. A slide hammer was used to pound the probe into the ground. Once the probe was at the desired depth, a portable vacuum pump was used to purge the gas from the soil. The portable pump was powered by electricity from the sampling vehicle. The procedure for purging and sample collection was the same as described above.

Before the sample was injected, the chemist would transfer from the 10 ml syringe an aliquot of sample into smaller syringes of the 1 microliter to 2 milliliter range. The sample injection size was based on CDM's knowledge of the area. Smaller injections were made in areas where background information indicated a strong possibility of contamination, as saturation of the gas chromatograph packed column was not desirable. If the area was not "hot", the sample was re injected with a larger volume of sample to achieve lower detection limits.

Quality Control

Quantification of compounds was achieved by comparison of the detector response of the sample with the response measured for calibration standards (external standardization). Instrument calibration checks were run periodically throughout the day as were system blanks to check for contamination in the soil gas sampling equipment. Ambient air samples were also routinely analyzed to check for background levels in the atmosphere.

Checks For Contamination

All sampling syringes were checked for contamination prior to sampling each day by injecting nitrogen carrier gas into the gas chromatograph. Microliter size sub sampling syringes were reused only after a nitrogen carrier gas blank was run to insure there was no contamination from previously injected samples.

A system blank was drawn through a randomly selected sample probe and adapter into decontaminated syringe. An aliquot sample of this blank was analyzed to determine the presence of contamination in the sampling apparatus.

Analytical Equipment Calibration

At the beginning of each day, standards of benzene, ethylbenzene, toluene, and xylene were analyzed to calibrate analytical equipment and determine daily response factors. Chemical standards were prepared in water from commercially available pure standards stored in methanol. Prior to running standards, water for standards was analyzed for purity. At least three standard injections were analyzed until resultant responses fell within 25% of each other. Response factors were then calculated based on these standard responses. Standards were repeated after every 5 samples to verify response.

Additional information on quality control and analytical procedures can be found in the Southeast Rockford Groundwater Contamination Phase I Final Quality Assurance Project Plan/Final Sampling and Analysis Plan, Dated February, 1991.

Deviations from the Proposed Work Plan

The proposed scope of work outlined in the Work Plan and Sampling Plan for Soil Gas Survey was fulfilled, however; slight deviations did occur during the duration of the project. Sample locations were added or subtracted from given areas based on field conditions. Table 2-1 presents the proposed number of samples for each area, actual number of sample locations, and describes the reasons the changes occurred.

2.4 Test Pit Investigation

Introduction

From June 15, 1993 through June 17, 1993, CDM performed a subsurface investigation of two locations in source area 7 (see Figure 4-9). The two locations were chosen based on the results of geophysical surveys (terrain conductivity and ground-penetrating radar), and soil gas survey results. The test pit investigation included preliminary soil borings, test pit excavation, and perimeter air sampling. Tests Pits were chosen as an investigative tool because of the large exposure of subsurface materials that could be accomplished. Exposure of the subsurface in this manner could give evidence as to the origin of any disposed material (labels, drums, containers, etc.) that might be present in the area.

Test Pit Soil Borings

To screen for the presence of hydrogen cyanide, hydrogen sulfide and volatile organics, soil borings were advanced at the test pit locations prior to excavation. If hydrogen cyanide had been found during the advancement of the soil borings, the test pit excavation would not have been performed due to the health risks associated with this compound. A total of eight soil borings were advanced; four at each excavation area (Figure 4-8). To provide adequate coverage of the area to be excavated, borings were positioned at the perimeter of the test pit. Soil borings were advanced to a total depth of 15 feet using 4.25 inch hollow stem augers. The augers were turned by a Mobile B-53 drill rig that was operated by OHM Corporation. All drilling operations were performed in level B personal protective gear. During drilling, the augers were paused every 2 feet and a 24 inch stainless steel split bore sampler, (split spoon) was driven inside the augers to collect a soil sample. Split spoon samples were collected every 2 feet until a total depth of 15 feet was accomplished. The soil samples were screened for hydrogen cyanide, hydrogen sulfide, and organic vapors by OHM personnel (see Table 2-2). After the desired depth was accomplished, the hollow stem augers were removed from the ground, and the remaining hole was backfilled with drill cuttings. Any portion of the hole not backfilled with drill cuttings was topped off with bentonite chips. Finally, a grass plug was used to cover the hole.

Table 2-1
Explanations for Deviations in the Soil Gas Study

Area	Number of Proposed Locations	Number of Actual Locations Sampled	Rational for the Change
1	17	17	No change from the work plan
2	12	11	One sample point removed due to space restriction between Harrison Avenue and Landfill
3	3	2	One sample point removed due to the presence of common traffic in the area.
4	27	18	A total of nine locations were eliminated. One location eliminated because access was denied near Patkus Machine. Three locations eliminated near the North west corner of the intersection of Alton and Marshall Streets due to utility clearance concerns, and the presence of a fence that obstructed access to the area. Four locations were eliminated the northeast corner of the intersection of Alton and Marshall Streets. The remaining points in this area were repositioned to cover the same amount of area while eliminating four of the proposed sample points.
5	10	7	Three sample points eliminated because of access issues with Northern Illinois Gas
7	13	15	Three sample points were added to better define the western extent of elevated soil gas readings in the area.
9	5	6	One sample point added to achieve a more complete coverage of the area.
10	23	20	Three sample points eliminated due to difficulties in obtaining access
11	19	5	A total of fourteen sample points were eliminated. Nine sample points were eliminated due to access denial by P & H partners. Five additional sample points were eliminated due to access difficulties with MC Chemicals.
12	12	11	One sample point eliminated by increasing grid spacing to cover same amount area with fewer sample points.
13	5	4	One sample point eliminated by increasing grid spacing to cover same amount area with fewer sample points.
14	66	61	A total of five sample points were eliminated in this area. One sample point was eliminated on the west side of the Borg Warner facility due to restricted egress into the area. Four sample points were eliminated on the east side of the Borg Warner facility. These sample points were removed since grid spacing was increased and the area could be covered with less sample points.
TOTAL	212	177	

Table 2-2
Vapor Monitoring Results From Soil Borings Collected at the Test Pits

Boring Number	Depth	Organic Vapors	Hydrogen Sulfide	Hydrogen Cyanide
TP1-SB1	1-3 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB1	3-5 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB1	5-7 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB1	7-9 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB1	9-11 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB1	11-13 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB1	13-15 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB2	1-3 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB2	3-5 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB2	5-7 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB2	7-9 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB2	9-11 Ft.	3 ppm	0 ppm	0 ppm
TP1-SB2	11-13 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB2	13-15 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB3	1-3 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB3	3-5 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB3	5-7 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB3	7-9 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB3	9-11 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB3	11-13 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB3	13-15 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB4	1-3 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB4	3-5 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB4	5-7 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB4	7-9 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB4	9-11 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB4	11-13 Ft.	0 ppm	0 ppm	0 ppm
TP1-SB4	13-15 Ft.	0 ppm	0 ppm	0 ppm
TP2-SB1	1-3 Ft.	1 ppm	0 ppm	0 ppm
TP2-SB1	3-5 Ft.	N/R	N/R	N/R
TP2-SB1	5-7 Ft.	15 ppm	0 ppm	0 ppm
TP2-SB1	7-9 Ft.	14 ppm	0 ppm	0 ppm
TP2-SB1	9-11 Ft.	140 ppm	0 ppm	0 ppm
TP2-SB1	11-13 Ft.	22 ppm	0 ppm	0 ppm
TP2-SB2	1-3 Ft.	1 ppm	0 ppm	0 ppm
TP2-SB2	3-5 Ft.	5 ppm	0 ppm	0 ppm
TP2-SB2	5-7 Ft.	15 ppm	0 ppm	0 ppm
TP2-SB2	7-9 Ft.	130 ppm	0 ppm	0 ppm
TP2-SB2	9-11 Ft.	220 ppm	0 ppm	0 ppm
TP2-SB2	11-13 Ft.	140 ppm	0 ppm	0 ppm
TP2-SB2	13-15 Ft.	160 ppm	0 ppm	0 ppm

Table 2-2
Vapor Monitoring Results From Soil Borings Collected at the Test Pits

Boring Number	Depth	Organic Vapors	Hydrogen Sulfide	Hydrogen Cyanide
TP2-SB3	1-3 Ft.	0 ppm	0 ppm	0 ppm
TP2-SB3	3-5 Ft.	0 ppm	0 ppm	0 ppm
TP2-SB3	5-7 Ft.	0 ppm	0 ppm	0 ppm
TP2-SB3	7-9 Ft.	0 ppm	0 ppm	0 ppm
TP2-SB3	9-11 Ft.	0 ppm	0 ppm	0 ppm
TP2-SB3	11-13 Ft.	0 ppm	0 ppm	0 ppm
TP2-SB3	13-15 Ft.	0 ppm	0 ppm	0 ppm
TP2-SB4	1-3 Ft.	0 ppm	0 ppm	0 ppm
TP2-SB4	3-5 Ft.	0 ppm	0 ppm	0 ppm
TP2-SB4	5-7 Ft.	0 ppm	0 ppm	0 ppm
TP2-SB4	7-9 Ft.	0 ppm	0 ppm	0 ppm
TP2-SB4	9-11 Ft.	0 ppm	0 ppm	0 ppm
TP2-SB4	11-13 Ft.	0 ppm	0 ppm	0 ppm
TP2-SB4	13-15 Ft.	0 ppm	0 ppm	0 ppm

Site Safety

During drilling activities, an exclusion zone was constructed around the excavation to impede access to the area. All subcontracted personnel involved in the drilling, or handling of split spoons were suited in Level B personnel protective gear including air line respirators, tyvek coveralls, splash shields, steel toe boots with rubber liners, and chemical resistant gloves. CDM personnel remained up wind and did not enter the exclusion zone at any time during the excavations. Before leaving the exclusion zone all personnel completed a through decontamination process. This process included scrubbing all material from the exterior of the tyvek suit, gloves, and boot covers with a solution ofalconox and water. The suit was then rinsed with distilled water. The gloves, boot covers and the tyvek suit were removed and discarded in 55 gallon drums for later disposal.

Decontamination

The drill rig used at the site could accommodate enough hollow stem augers to drill two borings, or drill 30 feet before having to decontaminate the augers. To decontaminate materials used while drilling, OHM mobilized a steel decontamination trough. All augers and other contaminated materials were placed over the trough and sprayed by a high pressure steam cleaner. The resulting water was captured by a sump in the trough, and then pumped into 55 gallon drums for subsequent removal and disposal. All hand held sampling equipment, (spatulas, stainless steel trays, and split spoons) were decontaminated at the excavation between samples. A solution ofalconox and water was used to scrub debris from the object. The object was then rinsed with tap water followed by a rinse with distilled water. All water generated from this decontamination process was mixed with the water generated by the steam cleaner, and drummed.

Test Pit Excavation

Results of the soil borings indicated no hydrogen cyanide was present in the excavation areas, which allowed test pit excavation to proceed. The purpose of the test pit excavations was to investigate and characterize the anomalies found during the soil gas and geophysical surveys. Two areas were located where excavations would be conducted. Test pit 1 (TP-1), the northern most excavation was located in an area of geophysical anomalies only. Test pit 2 (TP-2) the southern most excavation were positioned in such a manner as to address geophysical, as well as, soil gas anomalies. A detailed illustration of the test pit locations can be found on Figure 4-9. Both test pits were excavated to 10 ft. x 10 ft. x 15 ft. dimensions as per the IEPA approved work plan. In order to characterize any contaminants present in the test pits, soil samples were collected from the walls and bottom of the test pits at varying depths. The soil samples were selected for analysis by visual and organic vapor analyzer evidence of contamination. Soil samples collected from the excavation were analyzed for TCL organics, TAL inorganics, and TCLP organic and inorganic parameters. All personnel working inside the test pit exclusion zone were outfitted in level B protective gear. Decontamination procedures for the personnel were conducted as previously described.

Field Equipment Used

To accomplish the task of excavating the test pits, OHM mobilized a Caterpillar 225 excavator , and a caterpillar 225 drum grapppler to the test pit site. The excavator was outfitted with a brass edged bucket to prevent sparks, and a Plexiglas blast shield to protect the operator in case of an explosion. The drum grapppler was mobilized on site because drums were suspected in the area. The drum grapppler was to be used to remove any drums from the pit and place them in overpack containers supplied by OHM.

Equipment Decontamination

All equipment used while excavating the test pits was decontaminated with a high pressure steam cleaner between excavations. Water from this process was captured in the steel decontamination trough used during drilling operations. All water generated by the decontamination process was pumped to 55 gallon drums for storage and future disposal.

Test Pit Air Samples

To monitor ambient air quality at each excavation, and provide data that will likely be used to evaluate potential health risks associated with any future construction or excavation in the area, ambient air samples were collected from eight separate locations near the perimeter of each excavation. Three air samples were collected up wind of each excavation from three separate locations. Seven samples were collected down wind of each excavation from five separate locations. The ambient air samples were drawn through Tenax tubes containing activated carbon by use of a portable air sampling pump. The pumps were positioned on 4 foot high stakes to sample air from the breathing zone. Figure 4-10 illustrates the locations and sample numbers of the air samples collected from each excavation. The pumps were activated immediately before breaking ground, and were deactivated when the excavation was totally backfilled. The air samples were collected by OHM Corporation. Samples were labeled and packaged for shipment to the lab by CDM. All air samples collected from the excavations were analyzed for volatile organic compounds using EPA method TO1.

2.5 Monitoring Well Drilling and Installation

Introduction

From July 6 through October 12, 1993, 44 monitoring wells were drilled and installed during the Phase II investigation of the Southeast Rockford Groundwater Contamination Study Area (see Figure 3-3). Of the 44 monitoring wells, 36 were installed in the unconsolidated aquifer, 6 were installed in the dolomite (Galena/Platteville) aquifer, and 2 were installed in the St. Peter Sandstone aquifer. WTD Environmental Drilling of Schofield, Wisconsin was contracted by CDM to perform the drilling and installation activities. The primary objectives of installing monitoring wells at the site were to better define the nature and extent of groundwater contamination and determine to what extent contaminants had migrated from potential source areas into the groundwater. Secondary objectives were to gather additional information for

groundwater modeling, further define the local geology and hydrogeology of the study area, and evaluate potential remedial alternatives.

Drilling Methods

Hollow-stem augers were used to drill as many boreholes as was technically and economically feasible. Where this drilling method was impracticable due to presence of heaving sands or due to difficult drilling because of great depth, boreholes were drilled using the mud-rotary method. This method was required for wells installed in the western portion of the study area where depth to bedrock is at least 200 feet. At locations where drilling continued into the bedrock, the bedrock portion of the borehole was drilled using the air-rotary drilling method. Except as noted below, the boreholes were drilled with a minimum diameter of 6 inches, in order to allow an annular space of 2 inches between the 2-inch I.D. Type 304 stainless steel riser pipe and the wall of the borehole.

At locations where both the unconsolidated units and the bedrock were saturated, a 6-inch (inside-diameter) outer casing was installed in boreholes that penetrate the bedrock, in order to minimize interaquifer flow within the borehole (double cased). Such locations required that the borehole diameter be approximately 7 to 9 inches, in order to admit the 6-inch casing. When bedrock was reached at these locations, the 6-inch casing was installed approximately 5 feet into the bedrock and the annular space sealed with a high-solids bentonite grout. Drilling into the bedrock was then continued with air-rotary methods. Water was not added to the well during the air drilling as enough water was present in the natural formation to facilitate lifting the cuttings out of the borehole.

At MW112C, which was installed in the St. Peter sandstone, the unconsolidated and Galena-Platteville aquifers, as well as the Glenwood Formation were present. As a result, triple casing was required to minimize flow between any of these four units. A 10-inch casing was installed from the surface to the top of the Galena-Platteville, and a 6-inch casing was installed from the surface to the top of the Glenwood Formation. The 2-inch well pipe and screen were then installed in the St. Peter Sandstone. This required a borehole diameter of approximately 14 inches in the unconsolidated units and approximately 10 inches in the Galena-Platteville. After installing each casing, the annular space was sealed with a high-solids bentonite grout.

The drill rigs used during the Phase II monitoring well installation event were a BK Model 81, a Diedrich Model 50 (both used for mud rotary and hollow stem auger wells), and a Canterra Model 350 (used for mud and air rotary wells).

Groundwater Samples Collected During Drilling

In order to determine the optimal depth interval at which to set the monitoring well screen, groundwater samples were collected for vertical profiling purposes at 10-foot intervals during drilling at selected monitoring well locations. These samples were submitted to a local laboratory subcontracted to CDM for 12-hour turnaround GC analysis of halogenated VOCs. Upon receipt of the analytical results, the field geologist would determine the depth interval at

which the monitoring well screen was to be set. The depth interval was generally centered on the depth of the sample with the highest contaminant concentrations reported for that particular drilling location. At several locations, however, groundwater samples were collected to also determine the maximum depth penetration of contaminants in the aquifer system. At these locations, the well screen of the deep monitoring well was set at the deepest contaminated interval. This data is summarized and included as Appendix H12 to this report.

Collection of vertical profiling groundwater samples during drilling required two different collection methods, based on whether the aquifer material was unconsolidated or bedrock. In the unconsolidated aquifer, groundwater was sampled with a Hydropunch sampler that was driven from the base of the borehole into virgin aquifer material. In the bedrock, such a method was not possible, however, bedrock intervals were sampled by inserting a pump and inflatable packer assembly at varying depths in the borehole. Packer sampling was conducted in the open borehole. Although the packer inflation pressure was closely monitored, there is no guarantee that a perfect seal was maintained. It is possible that air rotary drilling can strip VOCs out of the groundwater near the borehole. To counteract this, approximately 3 volumes of groundwater was purged from the borehole before collecting a groundwater sample.

Monitoring Well Construction and Installation Methods

Monitoring well construction is schematically illustrated in the Southeast Rockford Groundwater Contamination Phase II Sampling and Analysis Plan dated April, 1993. The monitoring wells installed during the Phase II investigation were constructed with 2-inch diameter riser pipes, well screens, vented caps, and bottom plugs made of Type 304 stainless steel. At bedrock wells where the unconsolidated unit was saturated, an additional 6-inch I.D. outer casing was installed. The 2-inch riser pipes were flush-threaded, and joints wrapped with Teflon tape during installation to inhibit leakage. The well screens were either 5 or 10 feet long, and continuously wound, with a slot size of 0.010 inches.

The filter pack used at the screened interval was a silt-free silica sand which was sized according to the well screens used and the formations in which the materials were screened. The sand was placed in the bottom-most foot of the borehole to form a pad on which to set the well. The well was then placed, and the filter pack installed from the base of the screen to 2 to 3 feet above the top of the screen. A 1-to 2-foot thick fine silica sand filter collar was installed above the filter pack in order to prevent the bentonite grout seal from infiltrating the filter pack near the screen. A well seal of high-solids clay grout, or bentonite chips was then placed from the top of the filter collar up to two to three feet below the ground surface. The grout was tremmied into the annular space from the bottom, in order to prevent the formation of gaps in the well seal. The remaining two to three feet of the borehole was filled with concrete in which a protective well casing was set. The protective well casing was a minimum of 5 inches in diameter and equipped with a locking cap, to maintain the integrity of the well.

At locations where the well pipe rose above grade, the protective casing was approximately 5-6 feet in length, in order to allow the casing to extend 6 inches above the 2-3 foot stickup of the riser pipe. The protective outer casing has two 1/4-inch holes (weep holes) drilled

approximately 6 inches above ground level, to prevent the outer casing from filling with water. The outer casing was filled with washed pea gravel or coarse sand to 6 inches below the top of the riser pipe.

At well locations where the well pipe was at or below grade, a flush mount protective well casing was used. The flush mount casing was approximately 8 inches in diameter and 1.5 feet in length, of which 2 to 3 inches was left above grade. The remainder of the casing was cemented into place. A rubber gasket sealed locking well cap was placed on the well pipe and bolts on the cover were attached to the casing.

A concrete apron was installed at the ground surface around the protective outer casings. The concrete apron was sloped radially away from the well to facilitate surface drainage. The concrete apron was separated from the concrete plug in which the protective casing was set by a caulked joint in order to minimize the effects of frost heave. In the case of stick-up wells, where necessary, six-foot steel bumper posts were set in concrete around the well nests, in order to prevent damage to the wells from vehicles.

Monitoring Well Development

In order to remove silt and other fines from the screened interval of newly installed monitoring wells, the wells were developed with a surge and pump method. This development method entails connecting a solid PVC surge block to a cord which was lowered into the screened interval of the well. The surge block was then raised and lowered rapidly for the vertical distance of the screen. This surging action loosened up silt or mud deposits caked in the screened interval. After aggressively surging the well, a bailer, impeller type pump, or nitrogen air lift was used to remove at least 10 well volumes of water from the well. Deep wells with large well volumes or good flow rates were developed with an impeller type pump or nitrogen air lift. Shallow wells with small well volumes, or poorly recharging wells were developed with a bailer. Periodically, the pump or bailer was removed from the well and the surge block again lowered into the screened interval. This periodic surging would help to loosen up silt that was drawn in and trapped in the filter pack around the screen by the removal of water from the well. If after 10 well volumes, the water from the well was still cloudy, pumping or bailing would continue until the water clarity improved.

Equipment Decontamination Procedures

Between each monitoring well location, decontamination of large equipment (drill rigs, augers, and associated equipment) was performed at a decontamination station in close proximity to the monitoring well location. Decontamination consisted of high-pressure steam cleaning and scrubbing, as necessary. Decontaminated equipment was stored on plastic sheeting or aluminum foil preventing it from coming in contact with the ground surface and other potentially contaminated materials. The rear end of the drill rig was also steam cleaned between well locations.

Storage and Disposal of Generated Wastes

The drilling and sampling activities of the Phase II investigation generated liquid and solid wastes, including soil, drill cuttings, drilling fluids(bentonite mud), and personal protective equipment. Based on historical information gathered during Phase I investigation, wastes from areas where VOC concentrations were expected to be greater than 1 part per million were sealed in 55-gallon drums and placed in the secured drum storage area for subsequent disposal.

Deviations From the Work Plan

During Phase II monitoring well drilling and installation activities monitoring wells were added or removed from the original list of wells to be installed outlined in the approved work plan. The following is a list of the addition or subtractions that occurred:

- Monitoring well MW120 listed in the work plan was not drilled. CDM and IEPA agreed that the well was not necessary based on lack of significant soil gas readings in Source Area 1.
- Monitoring well MW122 listed in the work plan was moved from the western to the eastern portion of the site. An additional well was added at this location (MW122B) to get a better vertical profile of groundwater in the area.
- Monitoring wells MW131 and 132 were relocated. Initially these two wells were located downgradient of Area 5, however, no significant soil gas anomalies were present in Area 5 and the wells were moved to Source Area 12. The second wells in these nests (MW131B and MW132B) were not drilled because the new locations only required an investigation of the shallow aquifer.
- Monitoring well MW134C was added to the MW134 nest. The well was added in an attempt to get a full vertical profile of contamination distribution immediately downgradient of Area 7.
- Monitoring wells MW136B and C were not installed at the MW136 monitoring well nest. These two wells were removed because open-hole packer samples were collected at depth eliminating the need for the proposed wells.
- Monitoring well MW137 was removed from the list of well in the work plan as low soil gas results in area 14 deemed it unnecessary.
- Monitoring well MW141 was moved from Area 14 due to the lack of soil gas anomalies detected in the area. The well was placed near the potential source area east of the intersection of Harrison Avenue and 20th Street.
- Monitoring well MW142 was added to the wells listed in the work plan. The well was added to evaluate the nearby potential source area to the east of the intersection at Harrison Ave. and 20th Street.

2.6 Soil Sampling

From June 21 through December 3, 1993, CDM collected 116 subsurface soil samples during the Phase II soil boring and monitoring well installation activities for the Southeast Rockford Groundwater Contamination study area. Additionally 10 surface soil samples were collected at various locations in Area 4 and Area 7. Subsurface soil samples were collected for analytical, geotechnical and lithologic purposes. Surface samples were collected only for analytical purposes.

Analytical Samples

During drilling activities at the site, subsurface soil samples were collected with a 2-inch split spoon sampler in accordance with ASTM standards. The sampling interval was generally five foot intervals for source investigation wells and borings, and 10 foot intervals for groundwater investigation wells. The samples were analyzed (to the extent possible, depending on sample recovery) for Target Compound List (TCL) Organics and Target Analyte List (TAL) Inorganics. The samples were field-screened prior to collection with an organic vapor monitor (OVM). In general, the two samples exhibiting the highest and the lowest detectable concentrations of VOCs were collected for analysis. For borings that did not indicate VOC readings from field-screening, the soil sample nearest the water table was collected for analysis.

Analytical samples were collected for the following reasons: 1) to define soil contamination near or at potential source areas (for source investigation wells and borings;) 2) to determine background soil chemical characteristics away from source areas; and 3) provide information about contaminant partitioning between the groundwater and soil media, which is in turn important to define in assessing both contaminant plume migration and remediation alternatives. A total of 126 soil samples (surface and subsurface) were collected for analysis during the Phase II soil sampling event.

Geotechnical Samples

To assess the proportion of clay-sized materials available for adsorption of organics in the site aquifers, and to assist in the analysis of hydraulic conductivity of the aquifers, five subsurface soil samples were submitted for geotechnical analysis. This analysis included grain size and hydraulic conductivity analysis. The geotechnical samples were collected from MW114B, MW133, MW101A, MW122, and MW114. As with the samples selected for analytical purposes, the samples for geotechnical analysis were selected to be representative of the lateral and vertical variations in the unconsolidated stratigraphic units across the study area. Geotechnical samples that were analyzed for hydraulic conductivity were collected with 3-inch diameter shelly tubes. Samples that were collected for grain size analysis only were collected with a standard 2-inch split spoon.

Lithologic Samples

During the Phase II soil sampling event, lithologic samples were collected to gain a clear understanding of the nature of the materials penetrated by the boreholes, to assist in stratigraphic correlation of clay deposits, and to define preferential pathways of groundwater (and contaminant) migration. The lithologic samples were visually inspected and classified by CDM's onsite geologist. All subsurface soil samples collected during the Phase II sampling event were used for lithologic purposes.

Surface Soil Samples

During Phase II, surface soil samples were collected to aid in determining if contamination was present at the surface in Areas 4 and 7. Samples were collected by cutting a grass plug from the area with a garden trowel, then collecting soil from the area. The soil was put into the appropriate containers, and the grass plug was replaced.

Decontamination Procedures

Between each sample location, decontamination of large equipment (drill rigs, augers, and associated equipment) was performed at a decontamination station in close proximity to the boring location. Decontamination consisted of high-pressure steam cleaning and scrubbing, as necessary. Decontaminated equipment was stored on plastic sheeting or aluminum foil preventing it from coming in contact with the ground surface and other potentially contaminated materials.

Sampling equipment, including split-spoon samplers, reusable spatulas, and any other implements which came in contact with the samples were decontaminated by scrubbing with a dilutealconox and tap water solution, followed by a tap water rinse, and a final deionized water rinse. Decontaminated equipment was placed on or wrapped in clean tin foil prior to next use.

Storage and Disposal of Generated Wastes

The drilling and sampling activities of the Phase II investigation generated liquid and soil wastes, including soil, drill cutting, and personal protective equipment. The wastes were sealed in 55-gallon drums and placed in the secured area for subsequent disposal.

Deviations Form the Work Plan

The following deviations from the work plan occurred while conducting Phase II soil sampling activities:

- During drilling of source area soil borings, samples were collected in the saturated zone as well as the unsaturated zone. The work plan stated that samples would only be collected from the unsaturated zone. This deviation occurred in an attempt to define contamination zones in areas where seasonal water table fluctuations occur. Due to the wet spring in the local area, some depth intervals were saturated that

would have been above the water table during other years. Such intervals were sampled to provide adequate source characterization. In addition, sampling was continued below the water table in areas of continuous high contamination, until contaminants declined (based on organic vapor head-space readings).

- Geotechnical samples were not collected from every boring when analytical samples were collected as per the work plan. Geotechnical samples were only collected from five borings, as it was determined in the field that slug tests would better characterize hydraulic conductivity in the unconsolidated aquifer than numerous geotechnical samples.

2.7 Groundwater Sampling

Introduction

CDM conducted the Phase II groundwater sampling event from September 28, through October 20, 1993. A total of 165 groundwater samples were collected during the event (120 groundwater samples, 12 duplicates, 11 field blanks, and 22 trip blanks). The samples were collected from industrial wells, Illinois State Water Survey wells, existing monitoring wells (all CDM installed Phase I wells), and newly installed CDM Phase II monitoring wells. Table 2-3 lists all wells sampled, and the analysis performed on the samples. Table 2-4 lists industrial well sampled in Phase II. The primary objectives for the groundwater sampling event were as follows: 1) better define the lateral and vertical extent of contamination in the study area; 2) identify potential contaminant migration pathways from identified source areas to the site; 3) evaluate potential contaminant source areas; 4) better define the geology and hydrogeology of the study area; 5) provide data that will support groundwater modeling, a risk assessment, and evaluation of remedial alternatives.

Sampling Procedures and Equipment Used

Bailers

Disposable polyethylene, and stainless steel bailers were used to purge and collect samples from some wells in the study area. This method was performed on those wells which had slow recharge rates, were very silty, or held little water.

Upon arrival at the well an electric water tape was lowered down the well indicating the current water level in the well. A purge volume was calculated from the water level data, and purging was begun. A total of at least 3 well volumes were removed from the well. This was accomplished by raising and lowering the bailer into the water in the well on a dedicated nylon cord. Beginning after the removal of the third volume, water quality parameters were collected (pH, temperature, and specific conductance) with a Hydak water quality meter. By monitoring these parameters, the field team could better identify when the groundwater in the well had stabilized, thus eliminating excessive purge volume removal. The Hydak meter was calibrated at the beginning of the day and at staggered periods throughout the day. The sample was

TABLE 2-3
MONITORING WELLS SAMPLED DURING THE PHASE II
GROUNDWATER SAMPLING EVENTS

CDM WELLS	VOCs ONLY	FULL TCL ORGANICS AND TAL INORGANICS	GENERAL WATER CHEMISTRY PARAMETERS
MW101A	x		x
MW101B	x		x
MW101C	x		
MW101D	x		
MW102A	x		
MW102B	x		
MW102C	x		
MW103A	x		
MW103B	x		
MW103C	x		
MW103D	x		
MW104A	x		
MW104B	x		
MW104C	x		
MW105A	x		
MW105B	x		
MW105C	x		
MW105D	x		
MW106A	x		
MW106B	x		
MW106C	x		
MW107A	x		
MW107B	x		
MW107C	x		
MW108A	x		
MW108B	x		
MW108C	x		
MW109A	x		
MW109B	x		
MW109C	x		
MW109D	x		
MW110A	x		
MW110B	x		
MW110C	x		
MW111A	x		
MW111B	x		
MW111C	x		
MW112A	x		
MW112B	x		x
MW112C	x		x

TABLE 2-3 (Cont'd)
MONITORING WELLS SAMPLED DURING THE PHASE II
GROUNDWATER SAMPLING EVENTS

CDM WELLS	VOCs ONLY	FULL TCL ORGANICS AND TAL INORGANICS	GENERAL WATER CHEMISTRY PARAMETERS
MW113A	x		x
MW113B	x		
MW114A	x		x
MW114B	x		x
MW115A	x		
MW115B	x		
MW116A	x		
MW116B	x		
MW117A	x		x
MW117B	x		x
MW117C	x		x
MW118A	x		x
MW119A		x	
MW121A		x	
MW122A		x	
MW122B		x	
MW123A		x	
MW124A		x	
MW125A		x	
MW126A		x	x
MW126B		x	x
MW127A		x	
MW128A		x	x
MW129A		x	
MW130A		x	
MW132A		x	x
MW133A		x	
MW133B		x	
MW133C		x	
MW134A		x	
MW134B		x	
MW134C		x	
MW135A		x	x
MW136A		x	x
MW138A		x	
MW140A		x	
MW141A		x	
MW142A		x	

TABLE 2-3 (Cont'd)
MONITORING WELLS SAMPLED DURING THE PHASE II
GROUNDWATER SAMPLING EVENTS

CDM WELLS	VOCs ONLY	FULL TCL ORGANICS AND TAL INORGANICS	GENERAL WATER CHEMISTRY PARAMETERS
MW1	x		
MW5	x		x
MW9	x		
MW12	x		
MW17	x		
MW19	x		
MW20	x		
MW21	x		
MW22	x		
MW29	x		
MW32	x		
MW34	x		
MW36	x		
MW37	x		
MW38	x		
MW41	x		
MW43	x		x
MW45	x		
MW46	x		x
MW47	x		
IW1	x		
IW3	x		
IW4	x		
IW5	x		
IW7	x		
IW8	x		
IW9	x		
IW10	x		
IW11	x		
IW12	x		
IW13	x		
IW14	x		
IW15	x		
IW16	x		
IW17	x		
IW19	x		

TABLE 2-3 (Cont'd)
MONITORING WELLS SAMPLED DURING THE PHASE II
GROUNDWATER SAMPLING EVENTS

CDM WELLS	VOCs ONLY	FULL TCL ORGANICS AND TAL INORGANICS	GENERAL WATER CHEMISTRY PARAMETERS
IW20	x		
IW21	x		
IW22	x		
IW23	x		
IW24	x		
IW25	x		

TABLE 2-4
INDUSTRIAL WELLS SAMPLED IN PHASE II

IW1	1915-20th Ave. - Acme Solvents well 103S
(IW2)	Existing well - Not Collected (Out of Service)
IW3	1915-20th Ave. - Acme Solvents well G101
IW4	1915-20th Ave. - Acme Solvents well G104
IW5	1915-20th Ave. - Acme Solvents well G102
(IW6)	2210 Harrison - Suntec well MW6 - Not collected (well damaged)
IW7	2210 Harrison - Suntec well MW7
IW8	2210 Harrison - Suntec well MW1
IW9	2210 Harrison - Suntec well MW3
IW10	2524-11th Street - former Rockford Graphics MW1
IW11	2524-11th Street - former Rockford Graphics MW2
IW12	2020 Harrison - Borg-Warner well G101S
IW13	2020 Harrison - Borg-Warner well G101D
IW14	4960-28th Ave. - Erhardt-Leimer MW-10D (bedrock)
IW15	Sundstrand MW33 (bedrock)
IW16	707 Harrison - Rockford Products Mon. well W6
IW17	707 Harrison - Rockford Products Mon. well W3
(IW18)	E. Rockford Collision Ctr. - Not collected (Out of Service)
IW19	123 Energy Street - Commonwealth Edison
IW20	Sundstrand well MW34A
IW21	Sundstrand well MW34 (bedrock)
IW22	Sundstrand well MW41
IW23	Sundstrand well MW5 (bedrock)
IW24	Sundstrand well MW9 (bedrock)
IW25	Sundstrand well MW31 (bedrock)

Note: Except where indicated, wells are screened in the unconsolidated aquifer.

collected when measurements for all three parameters had stabilized (± 0.25 pH units, ± 50 umhos/cm, and $\pm 0.5^\circ\text{C}$) for three consecutive readings.

Samples were collected by raising a bailer of water from the well and pouring it into the appropriate sample containers. The sample was poured slowly into the container to avoid sample agitation. Samples were immediately put into a cooler with ice and stored until the samples could be transported to the CDM trailer for packaging.

Submersible Pump

In deep wells, wells that contained high amounts of water, and wells with fast recharge rates, submersible pumps, (Grundfos and Fultz pumps) were used to purge and collect groundwater samples. Both pumps were outfitted with either Teflon or reinforced polyethylene hose.

The same procedures to calculate water level and purge volume were used as in the bailer method of sampling. Once a purge volume was established the pump was lowered into the well. The pump heads were lowered into the screened interval when possible. Deep wells and wells where the pump head would get caught on inside joints prohibited this and water was pumped from the deepest level in the well that could be obtained.

After three well volumes were purged from the well, water quality parameters were collected. Water quality samples were collected using the same procedure as in the bailer method. When water quality parameters had stabilized, the Grundfos pump was slowed to a low flow rate. This was not possible with the Fultz pump as it has a fixed low flow rate. When the desired flow rate was achieved, samples were collected. Water from the well was directed into the appropriate sample container and slowly filled to avoiding agitation of the sample. Filtered inorganic samples were collected from a high capacity, .45 micron, in-line filter that was connected to the end of the pump hose.

In the event that a well was pumped dry before three volumes were removed, it would be allowed to recharge for 15 minutes and then pumped dry again. The sample was then collected during the next episode of recharge. Water quality stabilization parameters would not be collected in this situation.

Collected samples were immediately placed in a cooler with ice and stored until the samples could be transported to the CDM trailer for packaging.

Decontamination

All disposable polyethylene bailers were discarded after use. Stainless steel bailers were washed with a solution ofalconox and tap water, then rinsed with distilled water. Submersible pumps were decontaminated by running a slug of thealconox and water solution through the entire length of hose. The outside of the hose was also cleaned with the solution. Tap water was then run through the hose and used to rinse the outside of the hose. Finally a slug of distilled water was run through the hose. Pump heads were also cleaned by this method.

Water generated from decontamination was released to the ground surface, with the exception of water where visible contamination, or suspected high levels of contamination was present. In this case the water was containerized in 55 gallon drums for subsequent disposal.

Groundwater Analysis Methods Used

All groundwater samples were analyzed for volatile organics using CLP SAS drinking water detection limit methods. All new CDM installed Phase II wells were also analyzed for semivolatile organics, pesticides, PCBs, and inorganics including cyanide using CLP RAS methods. Approximately 20% of the wells were selected for general water chemistry analysis. This analysis included minerals, nutrients, total dissolved solids, and total suspended solids analysis. Table 2-3 lists all of the wells sampled during the Phase II groundwater sampling event and the corresponding parameters for analysis.

Deviations From The Work Plan

During the Phase II groundwater sampling event, the following deviations of the approved Work Plan occurred:

- PID readings were not initially collected at all wells before sampling began. Only wells with known high concentrations, (greater than 1 ppm total VOCs) and new wells where soil borings indicated high levels of contamination had PID readings collected.
- Water was not collected from five to ten feet below the water table as per the work plan unless that happened to be the same distance below the water table as the screened interval. Most wells were sampled with the pump head positioned in or near the screened interval. It is believed that a better representative sample of the aquifer could be obtained from the screened interval.
- Teflon bailers were not used as per the work plan. Disposable polyethylene bailers were used because of the decontamination time savings afforded by using them.
- Positive displacement bladder pumps outlined in the work plan were not used to collect groundwater samples; impeller type pumps were used instead. This change was made due to USEPA and independent research data that suggested that impeller type pumps were as effective for collecting volatile organic samples as bladder pumps (Knobel and Mann 1993).
- Deviations from the list of monitoring wells to be sampled in Table 5-5 of the Sample and Analysis plan were due to field conditions. Groundwater samples were added or subtracted from the list for the following reasons:

Added to the List

- Better access to industrial wells than was originally expected.
- To obtain better coverage of a given area.
- To better distinguish the vertical profile of contamination.
- To replace wells where access was impossible or the well was destroyed

Deleted from the list

- Well was removed, damaged, or out of service.
- Dry well due to seasonal fluctuations in the water table.
- Lack of anomalous soil gas results in an area where a well was to be installed.

A comparison of Table 5-5 in the Sampling and Analysis plan, and Table 2-3 of this document will better define which groundwater samples were added or deleted during the Phase II groundwater sampling event.

2.8 Hydraulic Conductivity Testing

In order to assess the permeability of the local aquifers, and determine relative groundwater flow rates and contaminant migration, hydraulic conductivity tests were performed on each of the monitoring wells installed during Phase II, and several Phase I monitoring wells not previously tested. This data was also used in groundwater modeling. Monitoring well testing occurred from September 7, through October 28, 1993. The method used to perform the conductivity testing was a slug test, where air pressure was used to depress water levels in the wells. This was accomplished by using a pressurized air source (air compressor) attached to a pressure regulator, which was in turn coupled to the well pipe by an adapter. Prior to the test, water levels were depressed to a level of 5 to 10 feet below the equilibrium level by applying constant air pressure, then allowed to equilibrate at that level. The test began by instantly releasing the air pressure through a large-diameter blow off valve. The water level recovery was electronically recorded with a Hermit Environmental Data Logger attached to a pressure transducer. Immediately after each test was run, water level records were printed and inspected in the field to assure that the data from each test had been properly recorded.

2.9 Monitoring Well Surveying

To determine well elevations with respect to mean sea level, elevations of ground surface adjacent to each well, and the top of the riser pipe of each well installed during the Phase II investigation were surveyed under contract to CDM by Missman Stanley and Associates of Rockford, Illinois. Well surveying was conducted during September and October of 1993. All of the surveyed wells were tied in with USGS bench marks located in the study area, and were surveyed to a vertical tolerance of plus or minus one-hundredth of a foot. In addition to elevations, horizontal locations were surveyed to the nearest tenth of a foot; these locations were

ted in with the state-plane coordinate system as per the approved work plan. In order to help tie the Phase I survey into the state plane coordinate system, several Phase I monitoring wells were re-surveyed. Additionally, all Area 7 soil boring locations were surveyed allowing them to be tied with the state plane coordinate system.

2.10 USGS Well Drilling and Installation

Introduction

From October 28, 1992 through January 25, 1993, three deep borings were drilled and two monitoring wells installed by the United States Geological Survey (USGS) at the Southeast Rockford Groundwater Contamination study area. The borings and wells were installed as a cooperative effort between the USGS, USEPA, IEPA, and CDM. The USGS's primary objectives for advancing the three borings at the site was to investigate and define the nature and extent of fractures in the dolomite aquifer. USEPA, IEPA, and CDM's objectives for the installation of the borings and the monitoring wells was to gather additional information for groundwater modeling, further define the local geology, hydrogeology, and contaminant distribution of the study area, and to evaluate potential remedial alternatives.

Drilling Methods

The mud rotary method of drilling was used to drill through the unconsolidated material overlying the bedrock at the boring locations. A 12-inch diameter tri-cone roller bit was used to advance the boring and polymer based drilling mud was used to lift debris out of the boring. When drilling encountered bedrock, the borehole was drilled using the air-rotary drilling method employing a 6 inch diameter air hammer bit.

At all three drilling locations, both the unconsolidated units and the bedrock were saturated, requiring the use of a steel outer casing installed in boreholes to penetrate the bedrock, in order to minimize interaquifer flow within the borehole (double cased). When bedrock was encountered, the casing was installed 5 feet into the bedrock and the annular space sealed with a high-solids bentonite grout and portland cement mix. Drilling into the bedrock was then continued with the air-rotary method. Water was added to the well during the air drilling to facilitate lifting the cuttings out of the borehole.

Borehole Logging

Upon completion of drilling activities at each boring, the bedrock portion of the borehole was geophysically logged. This was accomplished by the use of the following geophysical methods: three-arm caliper, natural gamma ray, acoustic televiewer, temperature resistivity, and single-point resistivity. The use of a heat-pulse flowmeter was attempted at the site; however, conditions necessitated the use of an impeller flow meter to log the boreholes. The USGS Borehole Geophysical Research Group performed the geophysical logging activities at the borings.

Packer Testing

In order to collect samples from 10-foot intervals in the bedrock borehole, packer testing was performed at all three well locations. Upon completion of the downhole geophysical logging, at least three volumes of water were removed from the open borehole, when possible with a submersible pump. Purging the boring of this initial volume removed standing water and fine grained particles. In order to isolate groundwater from the dolomite aquifer in 10-foot vertical sections, a packer assembly was lowered into the borehole and inflated at the desired interval. The packer assembly consisted of two neoprene fixed end packers separated by a 10-foot section of stainless steel screen. The riser pipe consisted of black iron. The packers were inflated with pressurized nitrogen gas. After the packers were inflated, three well volumes were purged from the assembly to insure a representative sample of water from the formation. During purging, water quality parameters were monitored (pH, temperature conductivity) and recorded. Water quality samples were collected in an in-line flow through cell connected to the pump. When purge water had been removed, samples were collected also using the pump. Samples collected from the packer assembly were analyzed for VOCs by an approved USEPA CLP lab.

Monitoring Well Construction and Installation Methods

Two monitoring wells were installed in the three borings drilled during the USGS investigation. Boring BH-3 was abandoned by USGS. Upon completion of the BH-3 boring, the hole was backfilled with bentonite grout to the ground surface, as per the Illinois Water Well Construction Code Dated 1992. Boreholes BH-1 and BH-2 had monitoring wells installed in these locations. Monitoring wells were constructed with 2-inch diameter riser pipes, well screens, vented caps, and bottom plugs made of type 304 stainless steel. At monitoring well BH-1, the outer casing installed during drilling was 6-inches I.D. Boring BH-2 had an 8-inch I.D. outer casing installed during drilling. The 2-inch riser pipes were flush-threaded, and joints were wrapped with Teflon tape during installation to inhibit leakage. The well screens were 10 feet long, and continuously wound, with a slot size of 0.010 inches.

Prior to setting the well screen, bentonite chips were used to backfill the borehole to the desired screening depth. The filter pack used at the screened interval was washed pea gravel. The gravel was emplaced across an interval of one foot above the bentonite to form a pad on which to set the well. The well was then placed, and the filter pack installed from the base of the screen to 2 to 3 feet above the top of the screen. A 1- to 2-foot thick silica sand filter collar was installed above the filter pack, overlain by a 5 to 6-foot thick bentonite seal in order to prevent the bentonite grout seal from infiltrating the filter pack near the screen. A small interval of fine silica sand was installed above the bentonite collar, and a well seal of high-solids clay grout, or bentonite chips was placed from the top of the fine sand filter collar to two to three feet below the ground surface. The grout was tremmied into the annular space from the bottom, in order to prevent the formation of gaps in the well seal. The remaining two to three feet of the borehole was filled with portland cement in which a protective well casing was set. The protective well casing was equipped with a locking cap and weep holes to maintain the integrity of the well.

At both wells installed during the USGS investigation the well pipe rose above grade approximately 4-6 inches (stick-up). The protective casings used at the well locations were approximately 2 ft in length. The casing was allowed to extend 2 inches above the 4-6 inch stickup of the riser pipe. The inside of the outer casing was filled with portland cement to 1 inch below the top of the riser pipe.

A concrete apron was installed at the ground surface around the protective outer casings. The concrete apron was sloped radially away from the well to facilitate surface drainage. The concrete apron was separated from the concrete plug in which the protective casing was set by a caulked joint in order to minimize the effects of frost heave.

Monitoring Well Development

In order to remove silt and other fines from the screened interval of newly installed monitoring wells, the wells were developed by USGS with a 1.7" Brainerd-Kilmon Piston Pump. CDM also developed the wells prior to sampling with a surge and pump method. This development method entails connecting a solid PVC surge block to a cord which was lowered into the screened interval of the well. The surge block was then raised and lowered rapidly for the vertical distance of the screen. This surging action loosened up silt or mud deposits caked in the screened interval. After aggressively surging the well, nitrogen air lift was used to remove 10 well volumes of water from the well. Periodically, the air lift assembly was removed from the well and the surge block again lowered into the screened interval. This periodic surging would help to loosen up silt that was drawn in and trapped in the filter pack around the screen by the removal of water from the well. If after 10 well volumes, the water from the well was still cloudy, pumping would continue until the water clarity improved.

Decontamination Procedures

Between each monitoring well location, decontamination of large equipment (drill rigs, augers, and associated equipment) was performed at a decontamination station in close proximity to the boring. Decontamination consisted of high-pressure steam cleaning and scrubbing, as necessary. Decontaminated equipment was stored on plastic sheeting or aluminum foil preventing it from coming in contact with the ground surface and other potentially contaminated materials. The entire drill rig was also steam cleaned between well locations.

Storage and Disposal of Generated Wastes

The drilling and sampling activities of the USGS investigation generated liquid and solid wastes, including soil, drill cuttings, drilling fluids (bentonite mud), and personal protective equipment. The wastes were sealed in 55-gallon drums and placed in the secured drum storage area for subsequent disposal.

2.11 Residential Well Sampling

Introduction

Phase II residential well sampling occurred from June 8 through June 10, 1993. Twenty-four residential wells (fifteen of which were sampled during the Phase I effort) were sampled to determine if the contaminant plume had migrated beyond its boundaries as determined in the Operable Unit, into areas where the houses have not yet been hooked up to the city water supply. Houses were selected using information gathered from the IEPA and USEPA. Table 6-1 lists all houses sampled during the Phase I and Phase II sampling events.

Field Procedures and Equipment Used

All residential wells were sampled following the sampling guidelines outlined in the Sampling and Analysis Plan. These procedures were consistent with those used for the Operable Unit sampling event. Prior to sampling, a water source located before any water softening devices was found (usually an outside hose bib). Water was allowed to run for approximately 10 to 15 minutes, purging the residential well holding tank of standing water. After the purge time had elapsed, pH, temperature, and specific conductance measurements were collected using a Hydak water quality meter (this meter was calibrated at the beginning of the day and at staggered periods throughout the day). The sample was collected when measurements for all three parameters had stabilized (± 0.25 pH units, ± 50 umhos/cm, and $\pm 0.5^\circ\text{C}$) for three consecutive readings. After the sample was collected the 40 ml vials were inverted and tapped to assure that no small air pockets were visible. Samples were immediately placed in a cooler with ice until the samples could be packaged and shipped for analysis.

All samples were labeled and packaged according to USEPA Contract Laboratory Program (CLP) procedures, and shipped to Weyerhaeuser Analytical and Testing Services in Federal Way, Washington. All samples were analyzed using CLP SAS drinking water detection limit methods for volatile organic compounds. Prior to the commencement of field work, methods were detailed in the Sampling and Analysis Plan (SAP) (April, 1993) and Quality Assurance Project Plan (QAPP) (March, 1993) for the Southeast Rockford Groundwater Contamination study area.

Deviations From the Work Plan

Six wells were subtracted from the proposed list of samples contained in the Work Plan, (409 Brooke, 804 Taft, 3301 Eighth, 3138 Eighth, 3226 Ninth, and 2929 Eleventh) and were replaced with five different wells (3302 Kishwaukee, 2955 Eleventh, 3245 Collins, 3201 Eighth, and 3218 Ninth). This deviation occurred because of access difficulties, residents hooking up to the new city water system, and site coverage issues; however, a total of 24 samples were still collected as per the work plan.

2.12 Residential Air Sampling

Two separate residential air sampling events were conducted by CDM. The first event was conducted in the subdivision adjacent to Area 7, August 25, and 26, 1993. The second event was conducted at residences located in Area 4, December 16 and 17, 1993. The purpose of both sampling events was to determine if volatile organic vapors had migrated from nearby source areas into confined residential spaces, particularly basements. The data generated from these two sampling events will likely be used in future risk assessment work for these areas. During the sampling event in Area 7, fourteen residences were selected for sampling, and during the sampling event at Area 4, six residences were selected for sampling. Sample locations are shown in Figures 4-24 and 4-25. 16 of the 20 total residences were selected due to their proximity to identified areas of high contamination in the source area. The remaining 4 residences, (2 in each source area) were selected as background sample locations (Table 2-5).

Sample Equipment and Procedures Used

All residential air samples were collected in six liter Summa canisters. Each canister was equipped with a flow restricting valve that was calibrated to allow the canister to draw a composite air sample over a 24 hour period. Before each canister was positioned, CDM inspected the canister for the presence of a vacuum. This was accomplished by means of a vacuum gauge during the Area 7 sampling. During the sampling event in Area 4, an initial attempt was made to determine the amount of vacuum in each canister by connecting a laboratory supplied air flow meter to each canister. The flow meter was not shipped to CDM with the proper fittings, however, so this method was unsuccessful. Vacuum gauges were also not supplied. The presence of a vacuum condition in Area 4 sample canisters was checked only by listening for the sound of a vacuum being broken when the canister was opened.

At each residence a Summa canister was placed in an open area in the basement, away from any obvious substances or containers that might interfere with the sample results. An effort was made to locate canisters near any sumps or basement cracks. A canister was also placed in an open area in the back yard of each residence. The objective of this canister placement scenario was to determine if residents may be exposed to volatile organic compounds from either the soil gas migration pathway, or from ambient air influx from outdoors to indoors. All residents were questioned prior to the sampling events by IEPA to assure that substances which may interfere with analytical results had not, or were not, being used at the general time of the sampling events.

Air samples collected from both sampling events were analyzed for vinyl chloride, 1,1-dichloroethene, 1,1-dichloroethane, 1,2-dichloroethene (total), 1,1,1-trichloroethane, 1,2-dichloroethane, trichloroethane, and tetrachloroethene. The samples were analyzed by EPA method TO-14 for these compounds.

CDM collected one nitrogen blank for the Area 7 sampling event, and two nitrogen blanks for the Area 4 sampling event. Blanks were filled with 99.998% ultra pure nitrogen from a local industrial welding supply firm. The blank samples were not collected in the same manner as the

Table 2-5: Phase II Residential Air Sample Information

Address	Source Area	Inside	Outside	Canister Number	Canister Activation Time	Canister Deactivation Time
2709 Norway Pine	7	X		9402B	7:06 AM	7:28AM
2709 Norway Pine	7		X	9401B	7:16 AM	7:30 AM
3526 Balsam Lane	7	X		9403B	7:27 AM	7:36 AM
3526 Balsam Lane	7		X	9440B	7:34 AM	7:38 AM
3404 Balsam Lane	7	X		9404B	7:53 AM	8:01 AM
3404 Balsam Lane	7		X	9437B	7:58 AM	8:03 AM
2731 Bavarian Lane	7	X		9438B	8:24 AM	8:09 AM
2731 Bavarian Lane	7		X	9439B	8:32 AM	8:12 AM
3212 Edelweiss	7	X		9471B	11:05 AM	10:29 AM
3212 Edelweiss	7		X	82593A	11:13 AM	10:31 AM
2816 Bavarian Lane	7	X		9469B	12:19 PM	6:32 PM
2816 Bavarian Lane	7		X	9474B	12:24 PM	6:34 PM
2727 Bavarian Lane	7	X		9467B	12:39 PM	12:23 PM
2727 Bavarian Lane	7		X	9470 B	12:44 PM	12:24 PM
2711 Edelweiss	7	X		9468B	2:02 PM	2:01 PM
2711 Edelweiss	7		X	82593D	2:07 PM	2:03 PM
2804 Foilage	7	X		9473B	2:38 PM	2:43 PM
2804 Foilage	7		X	82593E	2:43 PM	2:45 PM
3423 Balsam Lane	7	X		82593F	2:57 PM	2:56 PM
3423 Balsam Lane	7		X	9472B	3:02 PM	2:58 PM
3518 Scotch Pine	7	X		9453B	4:25 PM	4:21 PM
3518 Scotch Pine	7		X	82593I	4:29 PM	4:22 PM
3525 Scotch Pine	7	X		82593G	4:13 PM	4:13 PM
3525 Scotch Pine	7		X	82593H	4:16 PM	4:16 PM
3514 Balsam Lane	7	X		82593B	1:43 PM	1:47 PM
3514 Balsam Lane	7		X	82593C	1:47 PM	1:49 PM
3334 Bavarian Lane	7	X		82593J	5:42 PM	6:15 PM
3334 Bavarian Lane	7		X	9454B	5:46 PM	6:18 PM
2641 Marshall	4	X		12011	6:30 AM	6:30 AM
2641 Marshall	4		X	13660	6:34 AM	6:35 AM
2630 Sewell	4	X		05700	8:01 AM	7:50 AM
2630 Sewell	4		X	05407	8:05 AM	7:55 AM
2645 Marshall	4	X		10774	8:50 AM	8:51 AM
2645 Marshall	4		X	13673	8:52 AM	8:53 AM
2114 Alton	4	X		14012	9:05 AM	9:01 AM
2114 Alton	4		X	12943	9:10 AM	9:04 AM
3114 16th St.	4	X		12079	9:50 AM	9:45 AM
3114 16th St.	4		X	12715	9:55 AM	9:47 AM
3325 18th St.	4	X		05412	10:07 AM	10:05 AM
3325 18th St.	4		X	12010	10:12 AM	10:08 AM

residential samples. A polyethylene hose was connected to a nitrogen tank, and the other end to the Summa canister. A polyethylene tee was placed in line so ambient air could escape from the polyethylene hose before the sample was collected. After the hose was purged of ambient air, the valve on the Summa canister was opened, allowing the canister to immediately fill with nitrogen.

Deviations from the Work Plan

The IEPA approved work plan states that samples are to be collected during dry weather conditions, however; during Source Area 7 sampling a rain storm moved into the area overnight. Indoor and outdoor samples were collected during the storm. Also, during the Source Area 7 and Source Area 4 sampling events, Teflon hose was not placed on the collection orifices of the canisters. At all locations CDM was able to place the canisters in unobstructed areas so that the tubing was not necessary.



Section 3



Section
Three

Section 3

Results of Hydrogeologic Investigation

This section of the remedial investigation report presents and interprets the findings of the Phase I and Phase II hydrogeologic investigations. The field methods and procedures used to obtain the results have been described in the preceding sections.

3.1 Geology

3.1.1 *Geology of Winnebago County*

The city of Rockford is located in the southwestern portion of Winnebago County, Illinois. The county lies within the Rock River Hill Country physiographic province and is marked by rolling topography with elevations ranging from about 700 feet above mean sea level (MSL) in Rockford to over 900 feet MSL in other parts of the county. Several rivers and creeks are found in the county's watersheds, most of which drain into the Rock River, which flows in a predominantly north to south direction, ultimately emptying into the Mississippi River.

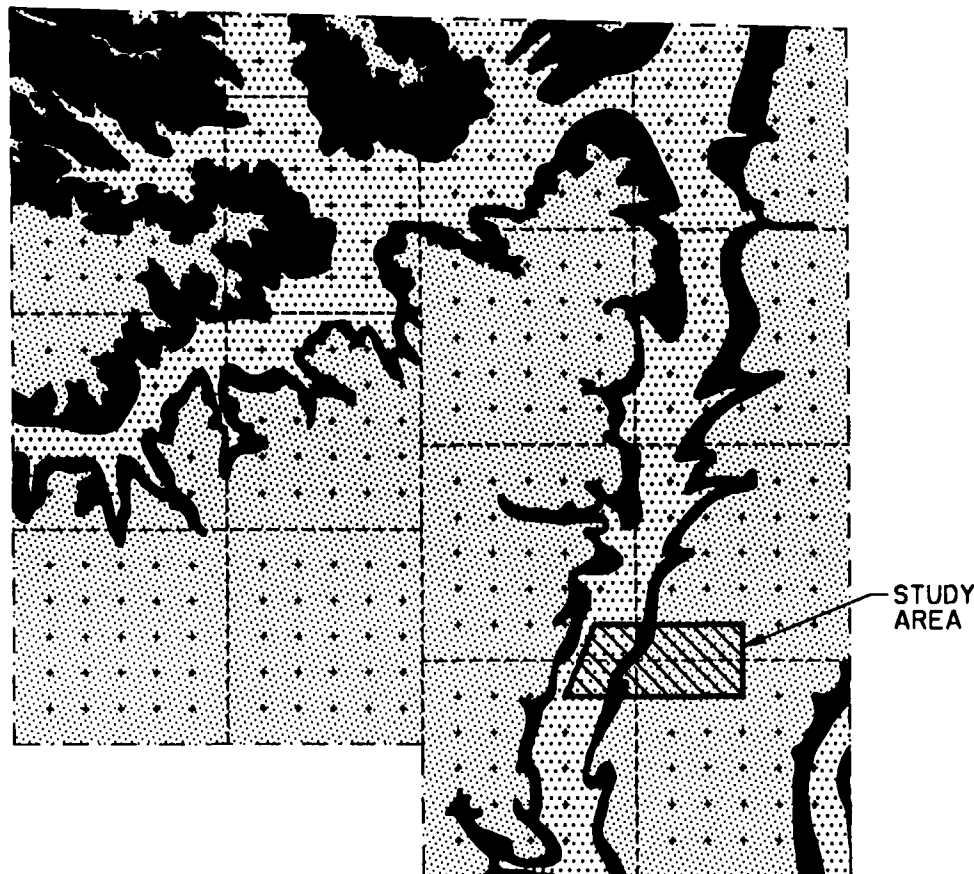
Subsurface sediments in Winnebago county are predominantly unconsolidated glacial sediments with lesser amounts of river-deposited sediments predominating in river and creek floodplains. River sediments mostly overlie glacial sediments. The glacially-derived sediments unconformably overlie a highly-eroded bedrock surface that ranges in elevation from less than 450 to over 900 feet above MSL. Pre-glacial bedrock valleys occur within the county. The bedrock valley found near the Rockford area is the Rock Bedrock Valley which trends north to south near the eastern edge of the county; another major bedrock valley (the Troy Bedrock Valley) which trends northeast to southwest, is found east of Rockford (Berg et al., 1984).

The topography and physiography of the county is generally controlled by the subsurface topography of the bedrock. Surface highlands reflect subsurface bedrock areas of higher elevation and river valleys and creeks reflect the subsurface valleys.




Paleozoic bedrock units found in Winnebago County include the Galena, Platteville, Ancell, and Prairie du Chien Groups; these strata overlie Cambrian Formations which overlie Pre Cambrian granite. Silurian dolomite and the Maquoketa Group are not present in the study area. Bedrock surfaces in the Troy and Rock Bedrock Valleys are predominantly the Ancell Group, with bedrock of younger age found as the flanks of the valleys. Since this region is part of the southeastern flank of the Wisconsin arch, the bedrock units have a regional dip to the southeast. A generalized stratigraphic column of Winnebago County is found as Figure 3-1, a bedrock surface map is found as Figure 3-2.

ERA	SYSTEM	SERIES	MEGA-GROUP	GROUP	FORMATION
CENOZOIC	QUATER-NARY	PLEISTO-CENE			
P A L E O Z O I C	O R D O V I C I A N	C H A M P L A I N I A N	O T T A W A	G A L E N A	DUBUQUE
					WISE LAKE
					DUNLEITH
					GUTTENBERG
				P L A T T E V I L L E	QUIMBYS MILL
					NACHUSA
					GRAND DETOUR
					MIFFLIN
					PECATONICA
					GLENWOOD
		C A N A D I A N	K N O X	A N C E L L	ST. PETER
					KRESS MBR.
				P R A I R I E D U C H I E N	SHAKOPEE
					NEW RICHMOND
					ONEOTA
					GUNTER
	C A M B R I A N	C R O I X A N	P O T S D A M		EMINENCE
					POTOSI
					FRANCONIA
					IRONTON- GALESVILLE
					EAU CLAIRE
					MT. SIMON
P R E C A M B R I A N					

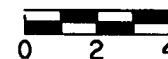
GENERALIZED STRATIGRAPHIC COLUMN
OF WINNEBAGO COUNTY



LEGEND:

-  GALENA GROUP
-  PLATTEVILLE GROUP
-  ANCELL GROUP

SCALE IN MILES



SOURCE: GEOLOGY FOR PLANNING IN BOONE AND WINNEBAGO COUNTIES.
BERG, KEMPTON, STECYK (1984).

SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY

BEDROCK SURFACE MAP OF WINNEBAGO COUNTY

CDM

environmental engineers, scientists,
planners, & management consultants

Figure No. 3-2

3.1.2 Geology of the Study Area

The Phase II study was completed primarily to delineate subsurface conditions west of the Phase I study area and to further investigate the Phase I area. The Phase II study area is bordered by South Mulford Road to the east, Sandy Hollow Road to the south, Broadway Street to the north, and the Rock River to the west, an area of approximately 10 square miles. The geology of the study area was determined during the Phase I and II drilling and from other studies (EDI Engineering and Science, 1989; Illinois EPA, 1988; Kay et al., 1994) and subsurface boring logs obtained from Illinois State Water Survey and the City of Rockford. (See Figure 3-3 for soil boring and monitoring well locations, see Appendix A for CDM soil borings logs.)

A variety of sources were used to characterize the geology and hydrogeology of the area. This included information for industrial wells, municipal wells and investigative wells as previously mentioned. Wells that were used for geologic interpretation only are shown on Figure 3-3 but are not listed on Tables 3-2 or 3-3. Only wells that were sampled and/or used for water level measurements during Phase II are shown on Table 3-2. All wells (including Phase I wells) used for interpretive or investigative purposes are shown on Figure 3-3.

As elsewhere in Winnebago County, the geology of the study area generally comprises highly-eroded bedrock overlain by unconsolidated glacial sediments of variable thickness. The study area contains an east-west tributary bedrock valley that merges westward into the Rock Bedrock Valley (see Figure 3-4). Observations from the Phase I and II studies and other drilling projects that were used to characterize the subsurface of the study area are described in the following sections.

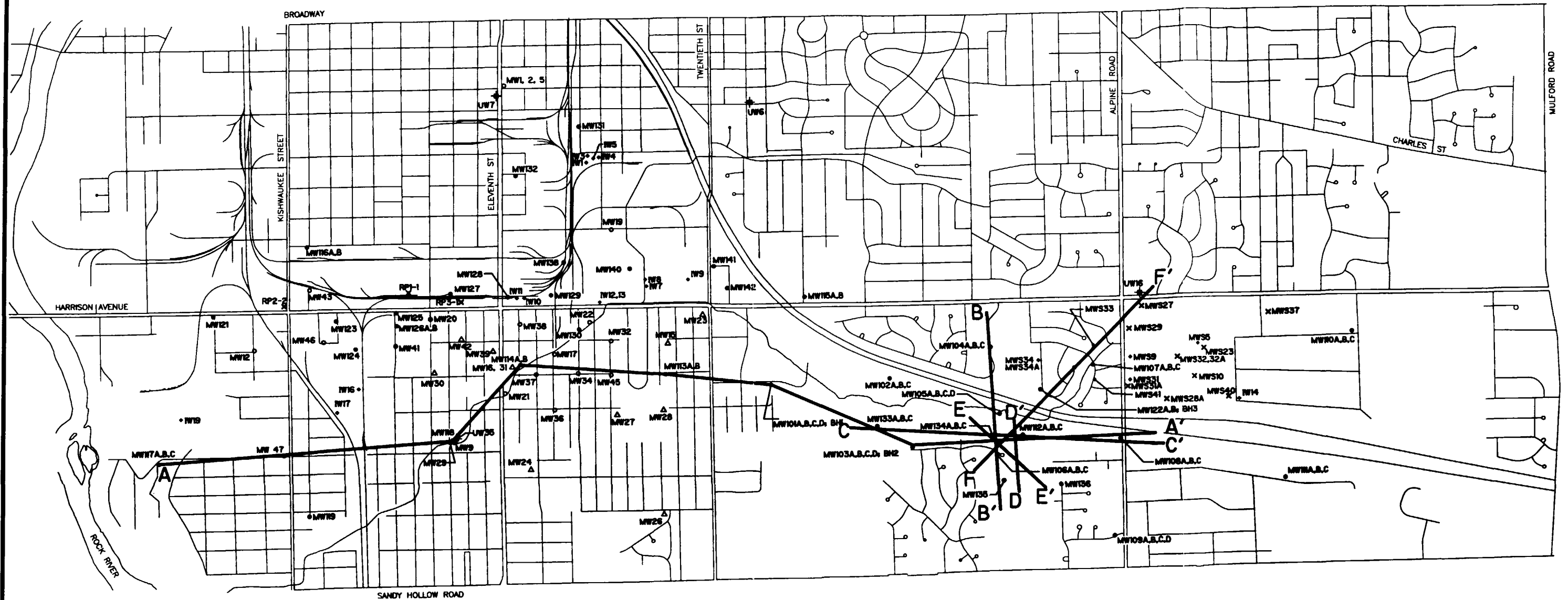
The approximate axis of the Rock bedrock valley (see Figure 3-4) was determined by reviewing Berg et al. (1984) and by borings completed in the sandstone at the western portion of the study area. The elevation of the sandstone from the Rockford Products Corporation well RP2-2 is consistent with the approximate elevation of the bottom of the bedrock valley delineated by Berg et al. (1984).

Bedrock

The topography of the bedrock surface of the study area is shown on Figure 3-4. This figure is based on depth-to-bedrock data obtained during Phases I and II and from other drilling efforts in the area. The overall shape of the bedrock surface is that of a narrow, east-west valley in the eastern portion of the study area (from the east boundary near South Mulford Road to 12th Street) that increases in depth to the west until the eastern floor of the Rock Bedrock Valley is encountered.

Three bedrock units of Ordovician age are present at the bedrock surface in the study area: the Galena, Platteville, and Ancell Groups. The Ancell Group consists of the St. Peter Sandstone and the overlying Glenwood Formation (Figure 3-1).

The elevation of the bedrock surface in the study area generally decreases from east to west with some variations due to tributary bedrock valleys. With the decrease in elevation, older bedrock

**LEGEND:**

- MW12 ISWS MONITORING WELL
- MW101 CDM/EPA MONITORING WELL OR WELL NEST; LETTER SUFFIX INDICATES SPECIFIC WELL OF A WELL NEST
- MW14 INDUSTRIAL SUPPLY WELL OR MONITORING WELL
- ✦ UW7 MUNICIPAL WATER SUPPLY WELL
- A—A' APPROXIMATE LINE OF SECTION
- △ MW30 ISWS WELL USED DURING PHASE I ONLY
- ✕ RP3-1 INDUSTRIAL SUPPLY OR MONITORING WELL



SCALE:
500 0 1000 Feet

SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY
**LOCATIONS OF WELLS AND GEOLOGIC
CROSS-SECTIONS**

R. SELIGA, NMW-CHI

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FIG 3-4

I:\CAD\1681\7\RI\RI\FIN\

CDM

environmental engineers, scientists,
planners, & management consultants

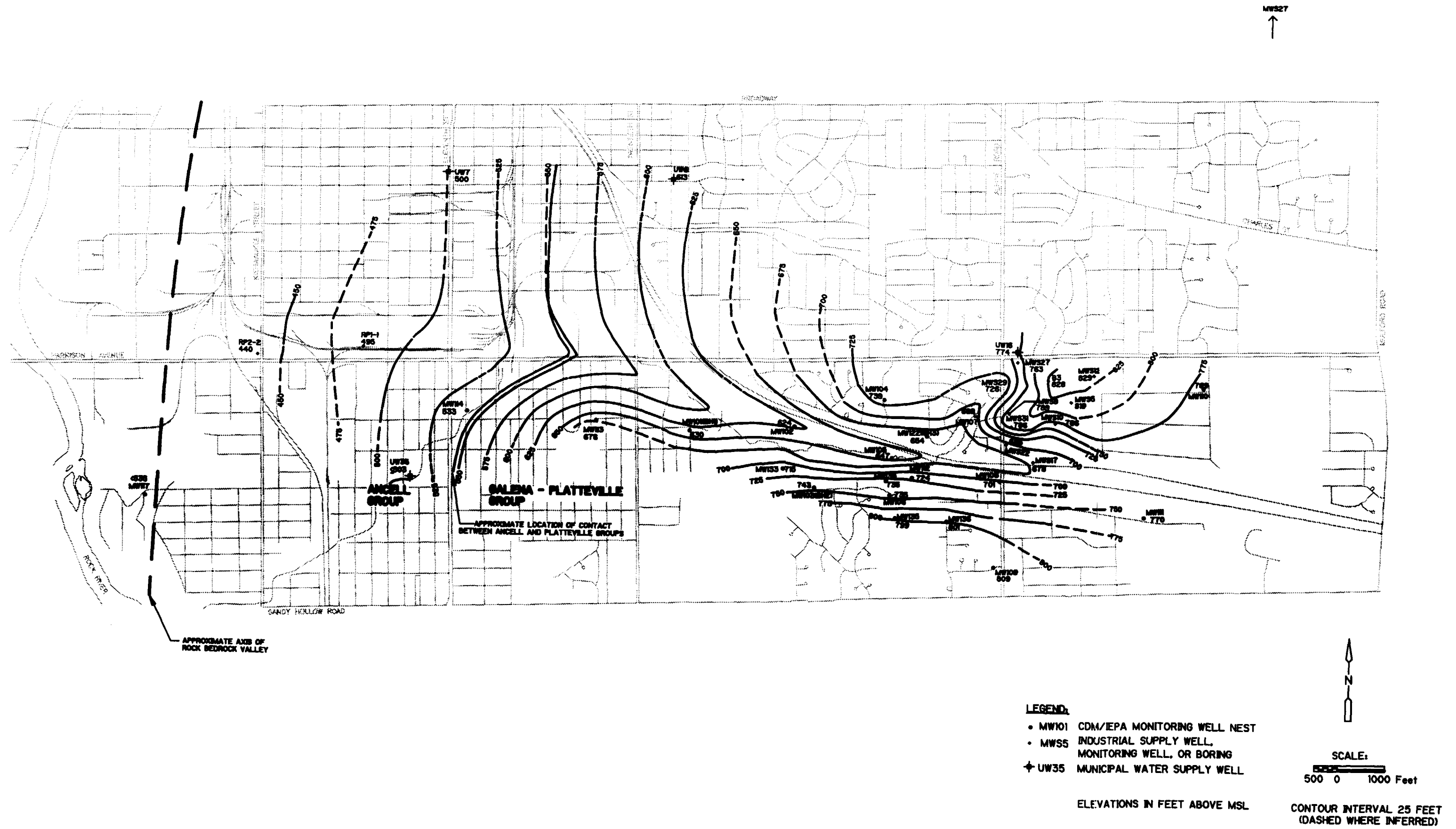


Figure No. 3-4

units occur at the bedrock surface. An east-west geologic cross-section which illustrates the stratigraphy of the bedrock groups is displayed as Figure 3-5.

Bedrock within the eastern portion of the study area (east of 20th Street) is predominantly tan to brown dolomite with variable but small amounts of chert and clay-rich horizons. The chert fraction of the drill cuttings was generally less than 10 to 20 percent and usually white or light gray. The clay was frequently brown and usually constituted less than 10 percent of the cuttings; small amounts of pale green shale were also observed. The observed lithology of the drill cuttings is consistent with the general description of the Galena Group given by other workers and with the known aerial extent of this stratigraphic unit in the Rockford area (Willman and Kolata, 1978).

Distinctive clay units known as bentonite beds occur within the Galena and the Platteville Groups and are reported to be very thin (generally less than 2 inches) in northern Illinois (Willman and Kolata, 1978). Bentonite beds were formed from the alteration of volcanic ash deposited during the Ordovician period. Brown, locally laminated clay-rich zones that generally resemble bentonite were identified in the dolomite bedrock at various elevations during the study; however, it was not possible to determine if the zones were bentonite beds due to the lack of sampling capability during bedrock drilling.

The bedrock surface near and west of 24th Street markedly decreases in elevation from east to west, exposing the Platteville Group in some areas. Drill cuttings from MW101 showed gray to tan, finely crystalline, fossiliferous dolomite, which agrees with other observations of the Platteville (Willman and Kolata, 1978).

West of MW113 the Platteville Group is absent and the Ancell Group units are present at the bedrock surface. Borings MW114 and UW7, and Rockford Products Corporation wells, RP1-1, RP2-2, encountered the Ancell Group as the uppermost bedrock unit. At MW112, the Glenwood Formation was encountered as a shale unit at the bedrock surface and was approximately 5 feet thick. At UW7, RP1-1, and RP2-2 the topmost bedrock unit is the St. Peter Sandstone. The observations of the St. Peter Sandstone at MW112 and MW114 are consistent with regional observations of the sandstone, as a tan to white, well-rounded, fine to coarse-grained quartz sandstone. The lithology of the Glenwood Formation appears to vary considerably in the Rockford area. Based on regional well logs, the formation appears to be predominantly dolomitic sandstone and shale with some members of the formation reported to be a green shale. The top of the Glenwood Formation was observed as green shale at MW112; this unit is the Harmony Hill Shale Member of the Glenwood Formation. The Harmony Hill Shale Member was not observed at MW114. This variation in lithology is consistent with observations of the Glenwood from other sources (Berg et al., 1984).

Porous or vuggy zones are common throughout the Galena and Platteville Groups (Willman and Kolata, 1978). Vugs are voids or cavities in rock that are larger than one-quarter inch, commonly formed by erosional processes or dissolution. Indications from CDM's investigation and from other investigations in southeast Rockford are that vugs are present throughout the Galena-Platteville dolomite.

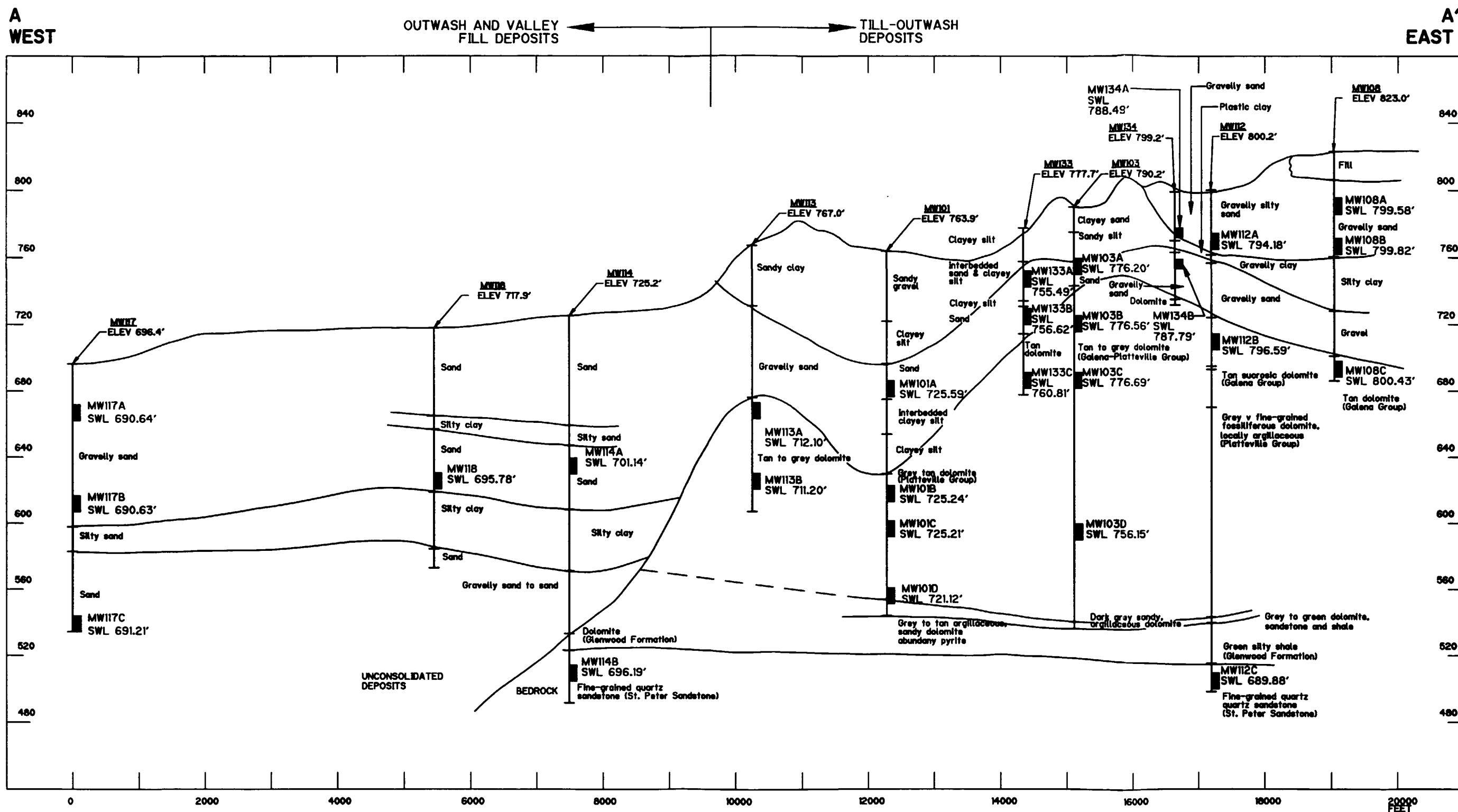
M. KUZEL, NMW-CHI

6:54:07

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FIG 3-5

\\CAD\1681\7\NRINRPT\



SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY

GENERALIZED GEOLOGIC
CROSS-SECTION A-A'

CDM
environmental engineers, scientists,
planners, & management consultants

Figure No. 3-5

Initial results of a study conducted by the USGS indicate that sub-horizontal fractures are present in the Galena-Platteville dolomite (Kay et al., 1994). These fractures were observed in subsurface borings. Fractures are important in that they influence the hydrogeologic properties of the bedrock. Bedrock fractures will be discussed further in subsection 3.2.

Unconsolidated sediments have filled the bedrock valley and buried the bedrock surface in the study area. The geology of the unconsolidated sediments is described in the following section.

Unconsolidated Sediments

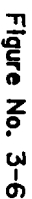
The majority of unconsolidated sediments in the study area are the result of glacial deposition during the Quaternary geologic time period. The surficial representations of the glacial deposits are the Mackinaw Member of the Henry Formation found in the western portion of the study area and the Nimitz Member of the Winnebago Formation located in the eastern part of the study area (Berg et al., 1984). The Mackinaw Member is generally a glacial outwash deposit of sand and gravel, while the Nimitz Member is predominately a till deposit of clay and silt with some sand and gravel. Lesser amounts of unconsolidated river sediments (Cahokia Alluvium) have been fluvially deposited by the Rock River and its tributaries.

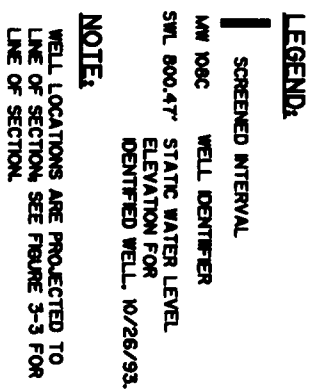
Generally, the sediments in the eastern portion of the study area are complexly interbedded till, and outwash deposits of sands, silts, and clays with silts and clays representing approximately 30 per cent of the unconsolidated sediments. Sediments west of 20th Street are predominantly sand with some gravel and discontinuous silt and clay layers. The upper portions of the sediments near the river are consistent with descriptions of the Mackinaw Member of the Henry Formation, which are sand and gravel glacial outwash deposits found near major river valleys. Clay units found in and at the base of the sands and gravels of the Mackinaw member are most likely lacustrine deposits from the Oregon Member of the Glasford Formation (Berg et al., 1984). Lower units are from earlier glacial depositional events.

Gravel and sand deposits found in the area are most likely the result of deposition by glacial meltwaters during events of glacial advancement and retreat (e.g. gravel at 720 to 760 feet elevation above MSL at MW101). The silt and clay found in the till materials in the east portion of the study are the result of direct deposition from the glaciers that moved across the area. Lacustrine deposits are the result of deposition in glacial lakes formed from the blockage of the glacial meltwater drainage system.

Many of the unconsolidated units are laterally discontinuous over short horizontal distances and vary in thickness between well location or grade into other types of unconsolidated materials. The highly variable geology is shown in Figures 3-5 through 3-10.

As an example of the discontinuity of the unconsolidated units, two clay layers (approximately 760 to 745 feet and 730 to 712 feet elevations) at MW105 do not exist a short distance away at either MW104, MW134, or MW106 (Figure 3-6). These clay units probably pinch out to the north and south, although the upper clay unit may grade laterally into the clayey silts at MW104 and MW106. Similarly, the 15-foot thick sand and gravel unit between the two clay units at MW105 thins to less than 5 feet at MW104 and MW106.





**SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY
GEOLOGIC
CROSS-SECTION C-C'**

Figure No. 3-7

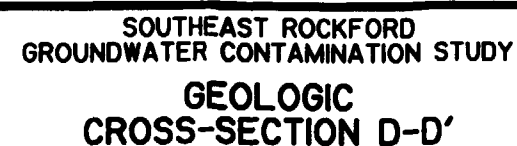
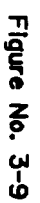


Figure No. 3-8





Unconsolidated units within the deeper parts of the bedrock valley abut against the sides of the valley. For example, the clayey silt unit at 680 feet MSL in MW105 (Figure 3-5) probably terminates against the bedrock surface to the south and may extend across to the northern flank of the valley. Parallel to the axis of the bedrock valley, the unconsolidated units typically exhibit lateral changes in thickness, grain size, and proportion of fine-grained sediment. The clay units at MW105 do not appear to extend very far to the east or west, whereas some units, such as the clay, sand, and gravel in which MW108, MW112, and MW134 are completed, appear to be traceable for greater distances than other units (Figure 3-5).

The sediments in the western portion of the study area are predominantly sands. However, a clay layer of up to 35-feet thick is found in MW117, MW41, UW7, RP1-3, and MW114 at an elevation of approximately 600 feet that appears to be extensive in the western portion of the study area. A second, intermittent clay layer, approximately 10-feet thick, is found in MW41, MW118, and MW114 at approximately 640 feet above MSL but was not found in MW116 or MW117. These layers are consistent with findings from another subsurface study in Rockford (Wehrmann et al., 1988) that shows lacustrine deposits from the Oregon Member of the Glasford Formation at these elevations in the west portion of the study area.

The complex lateral relationships in the east part of the study area (east of 20th Street) only allow for general stratigraphic correlation.

Particle-size analysis of the unconsolidated sediment provides information about the size distribution and the relative amounts of gravel, sand, and silt and clay in the aquifer. During Phase I, four split-spoon samples of representative aquifer material from the eastern portion of the study area were analyzed for particle-size distribution. In general, particle size was found to vary from less than 0.07 mm to approximately 20 mm (0.003-0.8 inches). Sand was the dominant particle size by weight in most samples, except for the sample from MW110, which had roughly equal amounts of sand and gravel. Silt and clay generally composed 10 percent by weight of the samples, with the exception of the sample from MW104, which contained 35 percent silt and clay.

Eight additional samples (OT126A, OT126B, OT130G, OT114A, OT114B, OT133, OT101A, OT122) were collected during Phase II for geotechnical analysis. The samples were analyzed for grain size; additionally, samples OT101A, OT133, and OT122 (samples primarily of clay with silt or sand) were analyzed for hydraulic conductivity using ASTM Method D5084-90, Hydraulic Conductivity Using a Flexible Wall Permeameter. Results of the conductivity tests show low conductivities, [OT101A (4.6×10^{-9} ft/sec), OT133 (5.6×10^{-7} ft/sec), and OT122 (1.3×10^{-9} ft/sec)]. Hydraulic conductivities of 10^{-9} ft/sec greatly inhibit migration of groundwater and contaminants. Results of the particle-size analyses and the hydraulic conductivity tests are presented on Table 3-1. Laboratory results are given in Appendix B.

TABLE 3-1
PARTICLE SIZE DISTRIBUTION AND HYDRAULIC CONDUCTIVITIES
UNCONSOLIDATED AQUIFER
SOUTHEAST ROCKFORD GROUNDWATER STUDY

Sample ID	Particle Size Distribution (Weight Percent)			Depth (ft)	Description	Hydraulic Conductivity (ft/sec)
	Gravel (4.7-20mm)	Sand (0.074-4.7mm)	Silt and Clay (<0.074mm)			
OT104	9	56	35	44-46	Gray brown clayey SAND, trace gravel	NM
OT105	15	74	11	74-76	Gray SAND with gravel, trace clay	NM
OT107	14	77	9	39-41	Brown SAND, trace gravel and clay	NM
OT110	49	42	9	39-41	Brown gravelly SAND, trace clay	NM
OT101A	0	7	93	57-59	Gray SILT and CLAY	4.6E-09
OT114A	0	22	78	47-49	Gray SILT with sand	NM
OT114B	0	92	8	4-6	Brown SAND with silt	NM
OT122	0	44	56	142-144	Gray sandy CLAY	5.60E-07
OT126A	0	99.6	0.4	45-47	Brown SAND	NM
OT126B	0	98.8	1.2	85-87	Brown SAND	NM
OT130G	0	99.3	0.7	35-37	Brown SAND	NM
OT133	0	19	81	45-47	Yellow/brown CLAY with sand	1.3E-09

NM= not measured

Test Methods: ASTM D2488-90, D422-63, D1140-54, D2488-91

3.2 Hydrogeology

3.2.1 Aquifers

Groundwater aquifers in the following three units are the focus of the investigation: the unconsolidated glacial sediments, the Galena-Platteville dolomite, and the St. Peter Sandstone. These aquifers will be referred to as the unconsolidated aquifer, the dolomite aquifer, and the sandstone aquifer, respectively. Details of wells installed in the aquifers that were used for data points during this study are shown on Table 3-2.

Unconsolidated glacial sediments are found throughout the study area; they generally overlie the dolomite aquifer in the eastern half of the study area and overlie the sandstone aquifer in the western half (see Figure 3-5). Bedrock topography reflects the presence of the pre-glacial Rock Bedrock Valley located in the western portion of the study area, and an east-west tributary valley located in the eastern portion of the study area. The deepest parts of the Rock Bedrock Valley contain the St. Peter Sandstone leaving the younger dolomite bedrock as the valley flanks. (Figure 3-4 delineates the extent of the sandstone [Ancell] and the dolomite [Galena-Platteville] at the study area.)

No areally continuous aquitards were encountered in the unconsolidated materials, indicating that the unconsolidated aquifer is hydraulically connected to the dolomite aquifer in the east half of the study area and the sandstone aquifer in the west. This is evidenced by static water levels in well nests where wells were screened in both the dolomite bedrock and the unconsolidated aquifers. Comparison of levels in MW101A to MW101C, MW103A to MW103B, MW107A to MW107C, and MW109A to MW109B all show static water levels within one-half foot (see Table 3-3). This small head would suggest that the aquifers are in hydraulic communication at these locations.

Additionally, well nest MW114 showed less than one foot of head difference between MW114A, screened in the unconsolidated aquifer and MW114B, which was screened in the sandstone. This suggests that the unconsolidated and sandstone aquifers are hydraulically connected at this location.

Several locations that have wells screened above and below clay layers show substantial differences in static water elevations. For example, both MW09 and MW29 are screened above a clay layer found at 665 to 658 feet above MSL in the western half of the study area. The head difference is typically one foot or less for these wells (Table 3-3). The head in MW118, located adjacent to MW09 and MW29 and screened below the clay layer, is approximately three to five feet lower than MW09 and MW29. Although periodic use of nearby municipal well UW35 may influence heads at this location, available data indicate that clay layers may create a semi-confined condition.

Within the unconsolidated aquifer, clay layers of significant thickness (up to 39 feet) were found in parts of the buried bedrock valley (e.g. at MW115, MW102 and MW105). Unsaturated clay horizons were observed in numerous borings in Area 7 (see Figures 3-8 and 3-9). These clay horizons are locally important in that they divert groundwater movement.

TABLE 3-2
GROUNDWATER MONITORING WELL DATA
SOUTHEAST ROCKFORD GROUNDWATER STUDY

Well Number	Depth to Screen Base*	Top of Screen Elevation	Bottom of Screen Elevation	Screen Length	Aquifer Screened	Top of Casing Elevation	Ground Surface Elevation
MW101A	88.0	686.1	676.1	10	unconsolidated	765.62	764.1
MW101B	150.1	624.0	614.0	10	bedrock	766.62	764.1
MW101C	172	602.0	592.0	10	bedrock	766.48	764.0
MW101D	212.8	561.1	551.1	10	bedrock	764.96	763.9
MW102A	35	761.5	751.5	10	unconsolidated	788.43	786.5
MW102B	98	698.6	688.6	10	unconsolidated	788.61	786.6
MW102C	184.3	613.4	603.4	10	bedrock	789.87	787.7
MW103A	41	759.5	749.5	10	unconsolidated	792.56	790.5
MW103B	75	725.4	715.4	10	bedrock	792.39	790.4
MW103C	107.9	692.3	682.3	10	bedrock	792.35	790.2
MW103D	200.5	599.7	589.7	10	bedrock	790.39	790.2
MW104A	77	748.9	738.9	10	unconsolidated	818.10	815.9
MW104B	121.9	703.3	693.3	10	bedrock	817.37	815.2
MW104C	146	680.1	670.1	10	bedrock	818.25	816.1
MW105A	22	771.3	761.3	10	unconsolidated	785.57	783.3
MW105B	54	739.6	729.6	10	unconsolidated	785.78	783.6
MW105C	95	698.5	688.5	10	unconsolidated	785.66	783.5
MW105D	156.8	637.3	627.3	10	bedrock	786.21	784.1
MW106A	40	773.5	763.5	10	unconsolidated	805.80	803.5
MW106B	86.4	727.0	717.0	10	bedrock	805.59	803.4
MW106C	119.4	694.0	684.0	10	bedrock	805.46	803.4
MW107A	38	781.3	771.3	10	unconsolidated	808.86	809.3
MW107B	66	753.3	743.3	10	unconsolidated	808.87	809.3
MW107C	140.4	678.8	668.8	10	bedrock	808.70	809.2
MW108A	39	794.0	784.0	10	unconsolidated	824.90	823.0
MW108B	61	771.9	761.9	10	unconsolidated	824.93	822.9
MW108C	134.3	698.8	688.8	10	bedrock	825.16	823.1
MW109A	32	826.7	816.7	10	unconsolidated	850.89	848.7
MW109B	60	798.5	788.5	10	bedrock	850.47	848.5
MW109C	85	773.4	763.4	10	bedrock	850.47	848.4
MW109D	39	819.0	809.0	10	bedrock	850.65	848.0
MW110A	40	814.2	804.2	10	unconsolidated	846.65	844.2
MW110B	71.3	782.8	772.8	10	unconsolidated	846.18	844.1
MW110C	111.4	742.8	732.8	10	bedrock	846.24	844.2
MW111A	35	805.7	795.7	10	unconsolidated	832.84	830.7
MW111B	58	782.7	772.7	10	unconsolidated	832.44	830.7
MW111C	97.3	743.4	733.4	10	bedrock	833.26	830.7
MW112A	35	774.9	764.9	10	unconsolidated	802.58	799.9
MW112B	95	715.3	705.3	10	bedrock	803.05	800.3
MW112C	300	510.2	500.2	10	sandstone	802.83	800.2
MW113A	105	677.0	662.0	15	bedrock	766.54	767.0
MW113B	155	621.4	611.4	10	bedrock	766.65	766.4
MW114A	95	639.9	629.9	10	unconsolidated	729.89	724.9
MW114B	220	515.2	505.2	10	sandstone	727.42	725.2
MW115A	100	711.9	701.9	10	unconsolidated	801.33	801.9
MW115B	130.5	682.4	672.4	10	unconsolidated	802.26	802.9
MW116A	79.5	664.2	654.2	10	unconsolidated	736.24	733.7

All measurements in feet, elevations are in feet above mean sea level.

* Depth to base of screen is distance from ground surface to base of screen.

Table displays only wells sampled and/or measured for water levels during Phase I II.

TABLE 3-2
GROUNDWATER MONITORING WELL DATA
SOUTHEAST ROCKFORD GROUNDWATER STUDY

Well Number	Depth to Screen Base*	Top of Screen Elevation	Bottom of Screen Elevation	Screen Length	Aquifer Screened	Top of Casing Elevation	Ground Surface Elevation
MW116B	164.5	579.3	569.3	10	unconsolidated	736.35	733.8
MW117A	39.5	666.9	656.9	10	unconsolidated	696.19	696.4
MW117B	89.5	616.9	606.9	10	unconsolidated	696.26	696.4
MW117C	159.5	546.9	536.9	10	unconsolidated	696.11	696.4
MW118	96.5	631.4	621.4	10	unconsolidated	717.59	717.9
MW119	59.5	667.0	657.0	10	unconsolidated	718.97	716.5
MW121	64.5	660.0	650.0	10	unconsolidated	716.98	714.5
MW122A	60	760.5	750.5	10	unconsolidated	810.47	810.5
MW122B	130	690.6	680.6	10	unconsolidated	810.33	810.6
MW123	45	689.9	684.9	5	unconsolidated	729.52	729.9
MW124	100	634.0	629.0	5	unconsolidated	731.30	729.0
MW125	45.5	692.4	682.4	10	unconsolidated	727.31	727.9
MW126A	54.5	683.4	673.4	10	unconsolidated	727.62	727.9
MW126B	84.5	648.4	643.4	5	unconsolidated	727.60	727.9
MW127	41.5	694.7	684.7	10	unconsolidated	728.59	726.2
MW128	43	690.8	685.8	5	unconsolidated	728.40	728.8
MW129	32	705.1	700.1	5	unconsolidated	732.12	732.1
MW130	37.5	700.5	690.5	10	unconsolidated	727.95	728.0
MW131	32.5	706.9	701.9	5	unconsolidated	736.95	734.4
MW132	33	700.7	695.7	5	unconsolidated	728.73	728.7
MW133A	35	752.6	742.6	10	unconsolidated	780.18	777.6
MW133B	58	729.5	719.5	10	unconsolidated	780.33	777.5
MW133C	96	691.7	681.7	10	bedrock	780.29	777.7
MW134A	27	777.1	772.1	5	unconsolidated	799.09	799.1
MW134B	45	758.9	753.9	5	unconsolidated	798.80	798.9
MW134C	63	741.2	736.2	5	unconsolidated	799.11	799.2
MW135	34	803.8	798.8	5	unconsolidated	835.19	832.8
MW136	45	794.9	789.9	5	bedrock	834.77	834.9
MW138	38	699.3	694.3	5	unconsolidated	734.79	732.3
MW140	36.5	706.4	701.4	5	unconsolidated	739.71	737.9
MW141	52	711.4	706.4	5	unconsolidated	758.06	758.4
MW142	53	711.1	706.1	5	unconsolidated	758.73	759.1
IW1	52.2	687.2	682.0	5	unconsolidated	736.42	734.2
IW3	52.2	688.0	683.0	5	unconsolidated	737.64	735.2
IW4	52.3	688.0	683.0	5	unconsolidated	737.71	735.3
IW5	52.0	688.5	683.5	5	unconsolidated	737.81	735.5
IW7	42.0	693.0	688.0	5	unconsolidated	NS	730.0
IW8	42.0	693.0	688.0	5	unconsolidated	NS	730.0
IW9	42.0	703.0	698.0	5	unconsolidated	NS	740.0
IW10	37.0	703.0	698.0	5	unconsolidated	NS	735.0
IW11	35.0	705.0	700.0	5	unconsolidated	NS	735.0
IW12 (G101S)	56.5	681.0	676.0	5	unconsolidated	734.74	732.5
IW13 (G101D)	94.6	643.0	638.0	5	bedrock	734.60	732.6
IW14	45.0	792.0	787.0	5	unconsolidated	NS	832.0
IW15 (MWS33)	120.0	700.0	690.0	10	bedrock	NS	810.0
IW16	36.0	694.0	684.0	10	unconsolidated	NS	720.0
IW17	33.0	697.0	687.0	10	unconsolidated	NS	720.0

All measurements in feet, elevations are in feet above mean sea level.

* Depth to base of screen is distance from ground surface to base of screen.

Table displays only wells sampled and/or measured for water levels during Phase I II.

TABLE 3-2
GROUNDWATER MONITORING WELL DATA
SOUTHEAST ROCKFORD GROUNDWATER STUDY

Well Number	Depth to Screen Base*	Top of Screen Elevation	Bottom of Screen Elevation	Screen Length	Aquifer Screened	Top of Casing Elevation	Ground Surface Elevation
IW19	75.0	660.0	650.0	10	unconsolidated	NS	725.0
IW20 (MWS34A)	105.0	730.0	720.0	10	unconsolidated	NS	825.0
IW21 (MWS34)	155.0	680.0	670.0	10	bedrock	NS	825.0
IW22 (MWS41)	70.0	750.0	740.0	10	unconsolidated	NS	810.0
IW23 (MWS5)	65.0	788.0	778.0	10	bedrock	NS	843.0
IW24 (MWS9)	53.0	789.0	779.0	10	bedrock	NS	832.0
IW25 (MWS31)	62.0	781.0	771.0	10	bedrock	NS	833.0
MW01	87.5	650.8	645.8	5	unconsolidated	734.06	733.3
MW02	50.5	687.8	682.8	5	unconsolidated	735.3	733.3
MW05	122.7	615.6	610.6	5	unconsolidated	735.58	733.3
MW09	47.9	673.2	668.2	5	unconsolidated	718.13	716.1
MW12	55.5	678.4	673.4	5	unconsolidated	730.97	728.9
MW15	49.5	699.7	694.7	5	unconsolidated	746.17	744.2
MW16	47.7	685.3	680.3	5	unconsolidated	728.04	728.0
MW17	43.3	686.5	681.5	5	unconsolidated	726.8	724.8
MW19	47.5	689.8	684.8	5	unconsolidated	734.33	732.3
MW20	51.6	675.8	670.8	5	unconsolidated	724.35	722.4
MW21	44.6	684.5	679.5	5	unconsolidated	726.14	724.1
MW22	43.5	689.7	684.7	5	unconsolidated	730.19	728.2
MW24	40.9	693.9	688.9	5	unconsolidated	731.75	729.8
MW26	70.3	692.7	687.7	5	unconsolidated	759.95	758.0
MW27	59.9	696.2	691.2	5	unconsolidated	753.06	751.1
MW29	34.9	686.4	681.3	5	unconsolidated	718.16	716.2
MW30	48.3	683.0	678.0	5	unconsolidated	728.29	726.3
MW31	60.4	670.4	665.4	5	unconsolidated	727.85	725.8
MW32	48.0	689.3	684.3	5	unconsolidated	734.3	732.3
MW33	44.0	694.8	689.8	5	unconsolidated	735.81	733.8
MW34	42.6	694.3	689.3	5	unconsolidated	733.88	731.9
MW35	42.8	688.6	683.6	5	unconsolidated	728.41	726.4
MW36	47.9	687.7	682.7	5	unconsolidated	732.56	730.6
MW37	44.3	686.1	681.1	5	unconsolidated	725.35	725.4
MW38	47.0	685.2	680.2	5	unconsolidated	729.15	727.2
MW39	51.4	685.1	680.1	5	unconsolidated	731.08	731.5
MW41	83.4	647.2	637.2	10	unconsolidated	722.59	720.6
MW42	51.8	680.3	675.3	5	unconsolidated	729.14	727.1
MW43	79.4	657.4	652.4	5	unconsolidated	733.8	731.8
MW45	70.4	680.6	670.6	10	unconsolidated	743.01	741.0
MW46	73.1	654.5	649.5	5	unconsolidated	724.65	722.6
MW47	53.0	685.7	680.7	5	unconsolidated	735.66	733.7

All measurements in feet, elevations are in feet above mean sea level.

* Depth to base of screen is distance from ground surface to base of screen.

Table displays only wells sampled and/or measured for water levels during Phase I II.

The clay layers in the eastern part of the study area appear to be localized and do not extend across the entire study area. Locally, clay layers and clay-rich zones probably cause the substantial (14-foot) head difference between the shallow (MW102A) and the intermediate (MW102B) depth well observed in October 1993 in the MW102 nest (see Table 3-3 for head differences).

The sandstone and the dolomite aquifers do not appear to be hydraulically connected in the area east of 20th Street. A comparison of water levels in well MW112C to MW112B typically show an approximate 100-foot head difference, most likely due to pumpage of the nearby municipal well UW16, located northeast of the MW112 cluster. This head difference shows that the dolomite and the sandstone are probably not hydraulically connected at this location, most likely due to the Harmony Hill Member of the Glenwood Formation which is an aquitard that separates the dolomite and the sandstone.

Porous or vuggy zones are common throughout the Galena Group (Willman and Kolata, 1978). Although it was not possible to determine the presence of distinct vuggy zones from drill cuttings, it is possible that vugs or vuggy horizons were responsible for the loss of drilling fluids and grout in wells MW104, MW108, MW109, and MW113 because of the greater porosity and permeability expected in these zones. Fractured zones, which could also be responsible for the loss of drilling fluids, could not be observed during drilling.

Results from a study (Kay et al., 1994) in the east portion of the study area suggest that vuggy zones were observed in the dolomite and subhorizontal fractures, most likely bedding planes, were observed in the lower portions of the dolomite. The study also indicated that, based on comparison of acoustic-televiwer and flow meter data, a concentration of flow in the dolomite aquifer is through subhorizontal fractures found in the lower parts of the dolomite. Additionally, a concentration of flow was observed in the upper few feet of the dolomite.

At MW108, loss of grout occurred in the gravelly zone above bedrock. At MW103 and MW109, loss of either drilling mud or grout occurred in the top 10 to 20 feet of bedrock. At MW103 and MW104, grout loss occurred approximately 50-55 feet below the bedrock surface during well installation. In addition, at location MW104, a localized solution zone containing fine-grained sediment was encountered during air-rotary drilling in bedrock. In the depth interval 80 to 100 feet, drill cuttings were predominantly brown, silty/clayey sediment (typically 70-90% by visual estimation) occupying solution cavities in bedrock; bedrock at MW104 is approximately 77 feet deep. Rapid advancement of the drill bit from 80 to 100 feet was also observed during the drilling of the borehole. This solution zone was not encountered in a borehole located twelve feet away, suggesting a localized extent of the solution feature.

Intergranular flow through an interconnected pore network is the pathway for groundwater flow in the unconsolidated and sandstone aquifers. Groundwater flow in the dolomite is under double porosity conditions: through intergranular flow, and through planar structures including low-angle bedding planes (as previously indicated) and through diffuse conduits (interconnected vugs, solution cavities, etc.). Vertical and inclined fractures have been observed in the dolomite nearby quarries (Kay et al., 1994) but have not been observed in the study area.

Wells MW103D and MW101D were both screened in the lower confines of the dolomite aquifer where subhorizontal fractures were identified during drilling and logging conducted by the USGS. Flow measurements indicated that the concentration of flow in the dolomite aquifer is through the subhorizontal bedding planes and the upper few feet of the aquifer; however, there is no evidence showing vertical interconnection of different bedding planes by high-angle fractures. Conductivities measured by CDM in these wells were the highest (2.4×10^{-4} ft/sec) and second highest (1.7×10^{-4} ft/sec), respectively, in the dolomite aquifer. This suggests that the bedding planes can be a significant flow pathway in the dolomite aquifer. The USGS report also indicated that vertical head differences increased with depth in the dolomite aquifer. Lastly, the report indicated that the effects of pumpage of the sandstone aquifer do not extend upward into the lower part of the dolomite aquifer as determined by a boring (BH3) approximately 2,750 feet from the pumped well.

3.2.2 Groundwater Flow

The direction of groundwater flow was determined from monitoring well water level measurements collected during the remedial investigation. Groundwater elevations for October 1993 and February 1994 are summarized on Table 3-3. Groundwater contours for the unconsolidated aquifer and the dolomite aquifer are shown in Figures 3-11 and 3-12, respectively. Groundwater elevations for the sandstone aquifer were not contoured because only two data points are available.

Based on CDM's study, the general direction of groundwater flow in the study area is to the west in both the unconsolidated and the dolomite aquifers. A previous study showed that the groundwater flow direction in the sandstone aquifer is complex due to several cones of depression from pumpage of the aquifer by the City and various industries such as Ingersoll Milling Machine Company, Essex International, Inc., and others (Visocky, 1993). In the unconsolidated aquifer, the flow in the eastern portion of the study area (20th Street to Alpine Road) is west with a slight northerly direction. When compared to the groundwater contours in the western portion of the study area (based on contours from wells MW111A to MW142), contours in the east are more closely spaced denoting a larger hydraulic gradient (0.012), most likely due to the influence of the low conductivity till materials found in the subsurface bedrock valley (see Section 3.1). From MW15 to MW128, the flow direction continues in the same direction; however, the gradient decreases significantly (0.0047) once groundwater encounters the higher conductivity materials (predominantly sands) found in the western portion of the study area. Past Eighth Street and to the river (in a line from MW128 to MW117) the gradient decreases again (0.001) and the flow direction turns to the southwest, probably due to the influence of the Rock River. An average gradient of .003 was calculated for the western portion of the study area; an average gradient of .006 was calculated for the entire unconsolidated aquifer.

TABLE 3-3
GROUNDWATER ELEVATIONS
SOUTHEAST ROCKFORD GROUNDWATER STUDY

LOCATION	TOC ELEV.	DTW 2/2/94	SWE 2/2/94	DTW 10/26/93	SWE 10/26/93	DTW 10/21-22/93	SWE 10/21-22/93
MW101A	765.64	42.04	723.60	40.05	725.59	40.06	725.58
MW101B	766.50	43.12	723.38	41.26	725.24	41.30	725.20
MW101C	766.48	43.00	723.48	41.27	725.21	41.32	725.16
MW101D	764.96	45.28	719.68	43.84	721.12	43.96	721.00
MW102A	788.43	23.18	765.25	22.69	765.74	22.66	765.77
MW102B	788.61	39.02	749.59	36.81	751.80	36.74	751.87
MW102C	789.87	42.62	747.25	39.97	749.90	39.98	749.89
MW103A	792.64	18.83	773.81	16.44	776.20	16.45	776.19
MW103B	792.45	18.31	774.14	15.89	776.56	15.90	776.55
MW103C	792.41	18.19	774.22	15.72	776.69	15.74	776.67
MW103D	790.39	37.20	753.19	34.24	756.15	34.25	756.14
MW104A	818.10	38.50	779.60	35.71	782.39	35.64	782.46
MW104B	817.37	38.82	778.55	36.08	781.29	36.00	781.37
MW104C	818.25	40.72	777.53	37.95	780.30	37.88	780.37
MW105A	785.57	4.30	781.27	3.49	782.08	3.46	782.11
MW105B	785.78	3.52	782.26	1.75	784.03	1.72	784.06
MW105C	785.66	5.29	780.37	2.52	783.14	2.53	783.13
MW105D	786.21	6.09	780.12	3.32	782.89	3.33	782.88
MW106A	805.71	18.61	787.10	15.86	789.85	15.83	789.88
MW106B	805.52	21.60	783.92	18.40	787.12	18.40	787.12
MW106C	805.40	20.46	784.94	17.16	788.24	17.15	788.25
MW107A	808.86	15.20	793.66	12.10	796.76	12.03	796.83
MW107B	808.87	15.12	793.75	12.03	796.84	11.96	796.91
MW107C	808.70	15.17	793.53	12.06	796.64	11.85	796.85
MW108A	824.90	28.39	796.51	25.32	799.58	25.19	799.71
MW108B	824.93	28.18	796.75	25.11	799.82	24.98	799.95
MW108C	825.16	27.91	797.25	24.69	800.47	24.57	800.59
MW109A	850.90	NM		25.17	825.73	25.01	825.89
MW109B	850.46	28.95	821.51	25.18	825.28	25.02	825.44
MW109C	850.46	29.13	821.33	25.34	825.12	25.19	825.27
MW109D	850.65	29.15	821.50	25.38	825.27	25.22	825.43
MW110A	846.65	29.24	817.41	22.82	823.83	22.62	824.03
MW110B	846.18	32.82	813.36	25.87	820.31	25.67	820.51
MW110C	846.24	33.34	812.90	26.46	819.78	26.26	819.98
MW111A*	829.69	NM		16.53	813.16	NM	
MW111B*	829.79	NM		16.84	812.95	NM	
MW111C*	829.82	NM		NM		NM	
MW112A	802.58	10.52	792.06	8.40	794.18	8.24	794.34
MW112B	803.05	9.70	793.35	6.46	796.59	6.39	796.66

All measurements in feet, measured from the north side of casing. Elevations are feet above Mean Sea Level (MSL).

TOC= Top Of Casing

SWE= Static Water Elevation

NM= Not Measured

* TOC elevation updated since Phase I

DTW= Depth To Water

TABLE 3-3
GROUNDWATER ELEVATIONS
SOUTHEAST ROCKFORD GROUNDWATER STUDY

LOCATION	TOC ELEV.	DTW 2/2/94	SWE 2/2/94	DTW 10/26/93	SWE 10/26/93	DTW 10/21-22/93	SWE 10/21-22/93
MW112C	802.83	116.15	686.68	112.95	689.88	113.70	689.13
MW113A	766.54	55.25	711.29	54.44	712.10	54.50	712.04
MW113B	766.65	56.28	710.37	55.45	711.20	55.47	711.18
MW114A	729.89	29.74	700.15	28.75	701.14	28.15	701.74
MW114B	727.42	32.16	695.26	31.23	696.19	29.96	697.46
MW115A	801.33	75.65	725.68	73.39	727.94	73.80	727.53
MW115B	802.26	76.39	725.87	74.44	727.82	74.60	727.66
MW116A	736.24	40.54	695.70	39.50	696.74	39.44	696.80
MW116B	736.35	NM		39.63	696.72	39.58	696.77
MW117A	696.19	6.41	689.78	5.55	690.64	5.41	690.78
MW117B	696.26	6.49	689.77	5.63	690.63	5.46	690.80
MW117C	696.11	5.77	690.34	4.90	691.21	4.73	691.38
MW118	717.59	22.83	694.76	21.81	695.78	20.14	697.45
MW119	718.97	26.72	692.25	25.54	693.43	25.46	693.51
MW121	716.98	23.43	693.55	22.38	694.60	22.28	694.70
MW122A	810.47	18.22	792.25	15.64	794.83	15.57	794.90
MW122B	810.33	18.63	791.70	15.65	794.68	15.57	794.76
MW123	729.52	33.92	695.60	33.25	696.27	33.16	696.36
MW124	731.30	36.31	694.99	35.19	696.11	35.10	696.20
MW125	727.31	NM		30.05	697.26	30.00	697.31
MW126A	727.62	NM		30.60	697.02	30.52	697.10
MW126B	727.60	NM		30.58	697.02	30.53	697.07
MW127	728.59	31.11	697.48	30.17	698.42	30.04	698.55
MW128	728.40	NM		29.03	699.37	29.81	698.59
MW129	732.12	NM		31.53	700.59	NM	
MW130	727.95	NM		23.39	704.56	NM	
MW131	736.95	NM	<701.64	>35.31	<701.64	>35.31	<701.64
MW132	728.73	NM		28.62	700.11	28.56	700.17
MW133A	780.18	26.91	753.27	24.69	755.49	24.61	755.57
MW133B	780.33	26.11	754.22	23.71	756.62	23.66	756.67
MW133C	780.29	21.80	758.49	19.48	760.81	19.45	760.84
MW134A	799.09	12.92	786.17	10.60	788.49	10.52	788.57
MW134B	798.80	13.42	785.38	11.01	787.79	10.96	787.84
MW134C	799.11	16.59	782.52	13.62	785.49	13.60	785.51
MW135	835.19	NM		35.88	799.31	35.76	799.43
MW136	834.77	34.58	800.19	31.37	803.40	31.20	803.57
MW138	734.79	35.16	699.63	34.25	700.54	34.27	700.52
MW140	739.71	33.65	706.06	32.81	706.90	32.86	706.85
MW141	758.06	NM		41.31	716.75	41.38	716.68

All measurements in feet, measured from the north side of casing. Elevations are feet above Mean Sea Level (MSL).

TOC= Top Of Casing

SWE= Static Water Elevation

NM= Not Measured

* TOC elevation updated since Phase I

DTW= Depth To Water

TABLE 3-3
GROUNDWATER ELEVATIONS
SOUTHEAST ROCKFORD GROUNDWATER STUDY

LOCATION	TOC ELEV.	DTW 2/2/94	SWE 2/2/94	DTW 10/26/93	SWE 10/26/93	DTW 10/21-22/93	SWE 10/21-22/93
MW142	758.73	43.61	715.12	40.41	718.32	40.44	718.29
IW1	736.42	36.47	699.95	35.70	700.72	35.70	700.72
IW3	737.64	37.65	699.99	36.88	700.76	36.87	700.77
IW4	737.71	37.44	700.27	36.67	701.04	36.67	701.04
IW5	737.81	37.66	700.15	36.90	700.91	36.89	700.92
MW01	734.06	34.35	699.71	33.69	700.37	34.67	699.39
MW02	735.30	35.64	699.66	34.97	700.33	34.96	700.34
MW05	735.58	33.84	701.74	33.18	702.40	33.18	702.40
MW09	718.13	18.49	699.64	17.58	700.55	17.56	700.57
MW12	730.97	36.58	694.39	35.48	695.49	NM	
MW15	746.17	35.80	710.37	34.97	711.20	35.01	711.16
MW16	728.04	25.64	702.40	24.85	703.19	24.88	703.16
MW17	726.80	NM		22.04	704.76	NM	
MW19	734.33	NM		30.47	703.86	30.49	703.84
MW20	725.07	27.91	697.16	26.84	698.23	NM	
MW21	726.14	24.01	702.13	23.22	702.92	NM	
MW22	730.19	NM		24.77	705.42	24.80	705.39
MW24	731.75	27.27	704.48	26.54	705.21	26.61	705.14
MW26	759.95	48.32	711.63	47.66	712.29	47.74	712.21
MW27	753.06	44.29	708.77	43.57	709.49	43.66	709.40
MW29	718.16	18.51	699.65	18.61	699.55	17.58	700.58
MW30	728.29	NM		30.56	697.73	30.51	697.78
MW31	727.85	25.38	702.47	24.61	703.24	24.64	703.21
MW32	734.30	28.30	706.00	27.49	706.81	27.53	706.77
MW33	735.81	30.88	704.93	30.12	705.69	30.16	705.65
MW35	728.41	NM		NM		23.59	704.82
MW36	732.56	NM		27.25	705.31	27.29	705.27
MW38	729.15	NM		27.63	701.52	27.62	701.53
MW39	731.08	NM		NM		30.48	700.60
MW42	729.14	NM		30.17	698.97	30.11	699.03
MW43	733.80	38.02	695.78	36.95	696.85	NM	
MW46	724.65	NM		28.17	696.48	28.11	696.54
MW47	735.66	42.30	693.36	41.13	694.53	41.07	694.59

All measurements in feet, measured from the north side of casing. Elevations are feet above Mean Sea Level (MSL).

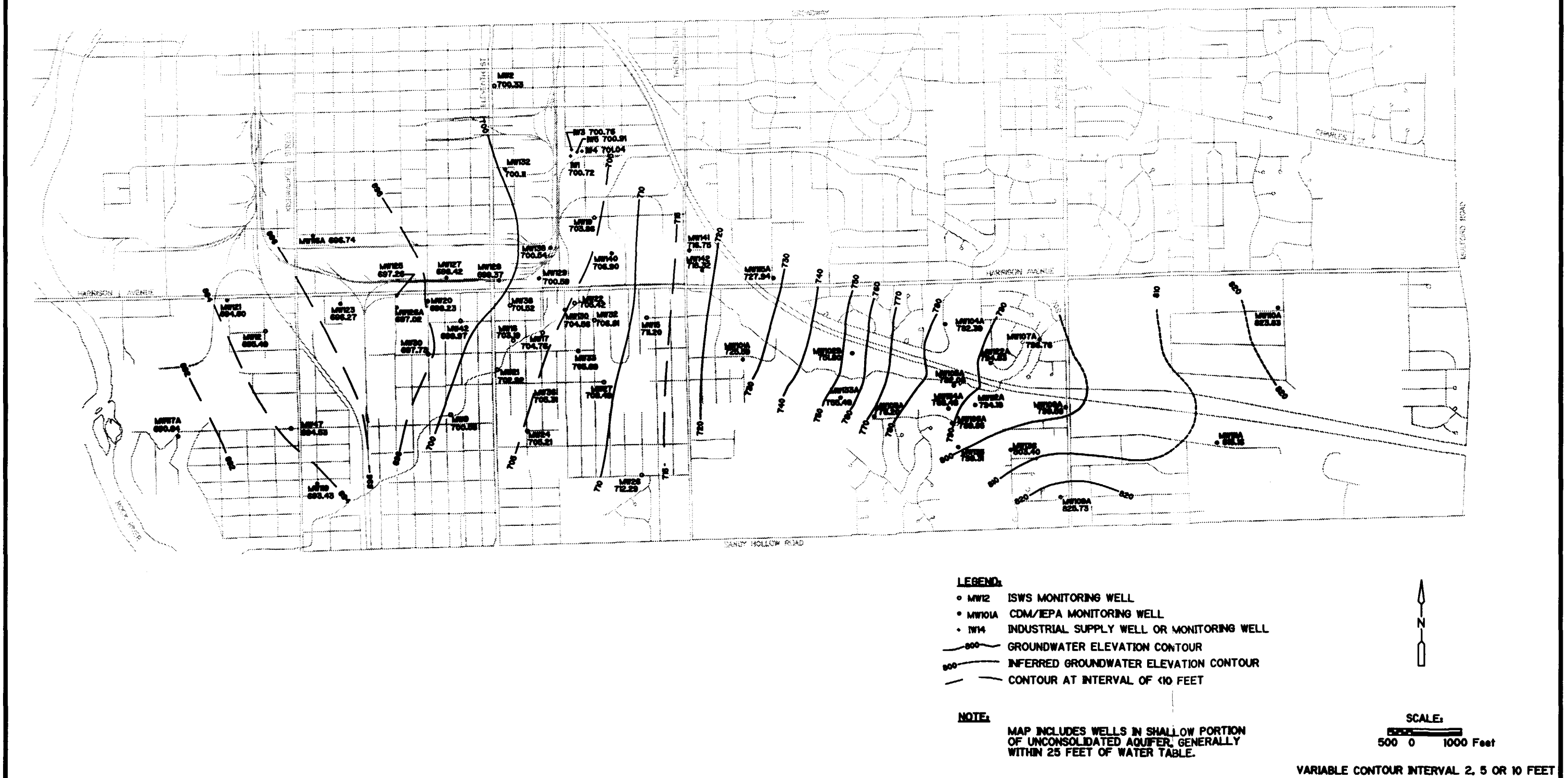
TOC= Top Of Casing

SWE= Static Water Elevation

NM= Not Measured

* TOC elevation updated since Phase I

DTW= Depth To Water



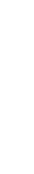
SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY
GROUNDWATER ELEVATIONS IN THE
UNCONSOLIDATED AQUIFER, OCT. 26, 1993

**LEGEND:**

- MW1018 CDM/IEPA MONITORING WELL
- IW14 INDUSTRIAL SUPPLY WELL OR MONITORING WELL

NOTE:

MAP INCLUDES WELLS IN SHALLOW PORTION OF BEDROCK AQUIFER, GENERALLY WITHIN 50 FEET OF UPPER BEDROCK SURFACE.



SCALE:
500 0 1000 Feet

CONTOUR INTERVAL 10 FEET
(DASHED WHERE INFERRED)

SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY
**GROUNDWATER ELEVATIONS IN THE
BEDROCK AQUIFER, OCT. 26, 1993**

Of the two wells installed in the sandstone aquifer (MW112C and MW114B) MW112C, in the east portion of the study area, MW112C showed a lower water elevation (689.13 feet MSL) than MW114B (697.46 feet). Although these elevations indicate the possibility of an easterly flow direction, the actual flow directions in the sandstone aquifer are multi-directional due to pumpage from municipal wells screened in the sandstone.

Vertical hydraulic gradients are present between the unconsolidated and bedrock aquifers, and within the dolomite aquifer (see Table 3-4). Vertical hydraulic gradients indicate the tendency of groundwater to flow vertically. Downward gradients exist at 10 of the 23 monitoring well nest locations where the vertical gradient was determined, with the largest occurring at MW134. The largest upward hydraulic gradient occurs at MW133. Geographically, the wells with an upward gradient are generally in the center of the study area, in an area bordered by Twentieth Street, Alpine Road, Harrison Avenue, and Sandy Hollow Road. An exception is well clusters MW1 and MW117, located in the western area of the study area, that also have upward gradients. Figure 3-13 illustrates the spatial distribution of vertical hydraulic gradients for the unconsolidated and dolomite aquifers.

Most of the wells with upward hydraulic gradients in the eastern part of the study area are located on the southern and eastern parts the bedrock valley. There is some lateral flow from the dolomite into the unconsolidated deposits in this area. The upgradient part of the buried bedrock valley may be serving as a discharge area for flow from the upper part of the dolomite aquifer.

3.2.3 Hydraulic Conductivity

Hydraulic conductivity is the capacity of rock or sediment units to transmit water. It is expressed as the volume of water that will move in unit time under a hydraulic gradient through a unit area measured at right angles to the direction of flow.

Hydraulic conductivity measurements were obtained using the slug test method as described in subsection 2.8. The Bouwer and Rice (1976) method was used to analyze the slug test data. Hydraulic conductivity (K) results are summarized on Table 3-5, complete results are given in Appendix C.

Hydraulic conductivities for the unconsolidated aquifer were determined for both the east and the west portion of the study area by testing 37 wells, 23 wells in the east section and 14 in the west. Conductivities for the dolomite aquifer were determined by testing 22 wells; 2 wells were tested in the sandstone aquifer. The range of conductivity values for the unconsolidated aquifer, both east and west portions, is 3.9×10^{-7} ft/sec in MW122B to 9.6×10^{-4} ft/sec in MW121 with a geometric mean of 3.9×10^{-5} ft/sec. For the east portion of the study area, the conductivity ranged from 3.9×10^{-7} ft/sec in MW122B to 7.8×10^{-4} ft/sec in MW102B with a geometric mean in the east unconsolidated materials of 4.0×10^{-5} ft/sec. The west portion of the study area showed conductivities of 1.6×10^{-6} ft/sec in MW114A to 9.6×10^{-4} ft/sec in MW121. The geometric mean of the west portion is 3.9×10^{-5} ft/sec.

TABLE 3-4
VERTICAL HYDRAULIC GRADIENTS
SOUTHEAST ROCKFORD GROUNDWATER STUDY

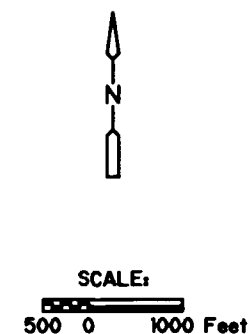
LOCATION	10/26/93 SWE	SCREEN BASE ELEVATION	MID SCREEN ELEVATION	HEAD DIFFERENCE	SCREEN DIFFERENCE	VERTICAL GRADIENT	GRADIENT DIRECTION
MW101A	725.59	677.62	682.62				
MW101B	725.24	616.52	621.52	0.35	61.10	5.73E-03	DOWN
MW102B	751.80	690.61	695.61				
MW102C	749.90	605.57	610.57	1.90	85.04	2.23E-02	DOWN
MW103A	776.20	751.56	756.56				
MW103B	776.56	719.39	724.39	-0.36	32.17	-1.12E-02	UP
MW104A	782.39	741.10	746.10				
MW104B	781.29	695.47	700.47	1.10	45.63	2.41E-02	DOWN
MW105A	782.08	763.57	768.57				
MW105C	783.14	690.66	695.66	-1.06	72.91	-1.45E-02	UP
MW105D	782.89	629.41	634.41	-0.81	61.25	-1.32E-02	UP
MW106A	789.85	765.71	770.71				
MW106B	787.12	719.12	724.12	2.73	46.59	5.86E-02	DOWN
MW107A	796.76	770.86	775.86				
MW107B	796.84	742.87	747.87	-0.08	27.99	-2.86E-03	UP
MW107C	796.64	668.30	673.30	0.12	102.56	1.17E-03	DOWN
MW108A	799.58	785.90	790.90				
MW108B	799.82	763.93	768.93	-0.24	21.97	-1.09E-02	UP
MW108C	800.47	690.86	695.86	-0.89	95.04	-9.36E-03	UP
MW109A	825.73	818.89	823.89				
MW109B	825.28	790.47	795.47	0.45	28.42	1.58E-02	DOWN
MW110A	823.83	806.65	811.65				
MW110C	819.78	734.84	739.84	4.05	71.81	5.64E-02	DOWN
MW111A	813.16	795.70	800.70				
MW111B	812.95	772.70	777.70	0.21	23.00	9.13E-03	DOWN
MW112A	794.18	764.90	769.90				
MW112B	796.59	705.30	710.30	-2.41	59.60	-4.04E-02	UP
MW113A	712.10	662.00	669.50				
MW113B	711.20	611.40	616.40	0.90	53.10	1.69E-02	DOWN
MW114A	701.14	629.90	634.90				
MW114B	696.19	505.20	510.20	4.95	124.70	3.97E-02	DOWN
MW115A	727.94	701.90	706.90				
MW115B	727.82	672.40	677.40	0.12	29.50	4.07E-03	DOWN
MW116A	696.74	654.20	659.20				
MW116B	696.72	569.30	574.30	0.02	84.90	2.36E-04	NONE*
MW117A	690.64	656.90	661.90				
MW117C	691.21	536.90	541.90	-0.57	120.00	-4.75E-03	UP
MW118	695.78	621.40	626.40				
MW29	699.55	681.30	683.80	-3.77	57.40	-6.57E-02	UP
MW122A	794.83	750.50	755.50				
MW122B	794.68	680.60	685.60	0.15	69.90	2.15E-03	DOWN
MW126A	697.02	673.40	678.40				
MW126B	697.02	643.40	645.90	0.00	32.50	0	NONE
MW133A	755.49	742.60	747.60				
MW133B	756.62	719.50	724.50	-1.13	23.10	-4.89E-02	UP
MW133C	760.81	681.70	686.70	-4.19	37.80	-1.11E-01	UP
MW134A	788.49	772.10	774.60				
MW134C	785.49	736.20	738.70	3.00	35.90	8.36E-02	DOWN

Elevations are feet above mean sea level

Head and screen difference are in feet

SWE= Static Water Elevation

* A head difference of 0.02 feet is not substantial enough to consider a gradient.



CDM
environmental engineers, scientists,
planners, & management consultants

TABLE 3-5
AQUIFER HYDRAULIC CONDUCTIVITIES
SOUTHEAST ROCKFORD GROUNDWATER STUDY

Mean of Aquifer Conductivities

	ft/sec	data pts.
Mean of Unconsolidated Aquifer	3.93E-05	37
Mean of East Unconsolidated Aquifer	3.96E-05	23
Mean of West Unconsolidated Aquifer	3.89E-05	14
Mean of Dolomite Aquifer	2.96E-05	22
Mean of Sandstone Aquifer	1.05E-04	2
Total		61

Range of Hydraulic Conductivities

	ft/sec
Maximum of Unconsolidated Aquifer	9.58E-04
Minimum of Unconsolidated Aquifer	3.88E-07
Maximum of Unconsolidated Aquifer East	7.84E-04
Minimum of Unconsolidated Aquifer East	3.88E-07
Maximum of Unconsolidated Aquifer West	9.58E-04
Maximum of Unconsolidated Aquifer West	1.60E-06
Maximum of Dolomite Aquifer	2.37E-04
Minimum of Dolomite Aquifer	2.86E-06

The mean conductivities of the east portion of the unconsolidated aquifer are similar to the western portion of study area. This is most likely due to the preferential placement of the wells into materials of higher permeability in the eastern portion of the study area.

Based on testing 22 wells, the range of hydraulic conductivities for the dolomite bedrock aquifer was 2.9×10^{-6} ft/sec in MW109B to 2.4×10^{-4} ft/sec in MW103D, with a geometric mean of 3.0×10^{-5} ft/sec. The mean K for the dolomite bedrock falls at the top of the range of values for limestone and dolomite (Freeze and Cherry, 1979).

Two wells (MW114B and MW112C) that were installed in the sandstone aquifer were tested for conductivity. The geometric mean for these two wells was 1.1×10^{-4} ft/sec.

Section 4

Section Four

Section 4

Results of Contaminant Investigation

4.1 Useability of Chemical Data

4.1.1 General

This section describes the quality assurance/quality control measures applied to the chemical data and the effect of these measures on the overall useability of the data. The specifics of data useability for each sample matrix is included in Appendix E. Samples collected included groundwater, residential well water, subsurface soil, surface soil, test pit soils and air, and residential air samples. During the Phase II study, 120 groundwater and 116 soil samples were sent for analysis. Thirty-four groundwater quality control samples were analyzed, including seven field duplicates, seven field blanks, and 19 trip blanks, and a sample of the drilling water. Four field duplicates were analyzed for the soil samples. Forty air samples were collected from residential basements along with 1 field duplicate and 2 field blanks. Also, 18 air samples were collected next to the test pits along with 2 field duplicates and 2 field blanks.

With the exception of the fast-turnaround screening samples for VOCs, all samples collected were analyzed through the USEPA's Contract Laboratory Program (CLP). For the Southeast Rockford Phase II Remedial Investigation, the analytical procedures for the CLP Laboratory are specified in the current USEPA CLP SOW OLM01.0 (8/91) for RAS low-medium concentration organic analyses, in the current CLP SOW ILM02.0 (9/91) for RAS low-medium concentration inorganic analyses, in the current CLP SOW (9/88) for high concentration organic analyses and in the current CLP SOW IHC01.1 for high-concentration inorganic analyses. The Phase II analytical methods are comparable to the Phase I methods because both were analyzed using CLP SOW procedures, and even though the SOWs are slightly different, the differences are in reporting procedures and not analytical methods. The analytical procedures for SAS CLP Laboratory analysis are specified in the SAS Client Request Forms provided in the Southeast Rockford Groundwater Contamination Phase II Quality Assurance Project Plan (QAPP) March 1993. The analytical method, SW846 8010, was used for the screening level volatile organic analysis performed by Analytical Laboratory Services of Rockford and is also provided in the Phase II QAPP.

4.1.2 Data Validation

Data reduction, validation, and recording were conducted in accordance with USEPA guidelines. Upon receipt of the analytical results from the CLP laboratory, CDM's validation staff reviewed the data. CDM validated 25 percent of the data in accordance with the procedures outlined in the QAPP. Each data package had 25 percent of the data validated. Samples chosen to be validated within each data package included samples that were critical to the investigation, background samples, anomalies from the Phase I investigation, and MS/MSD samples. If none of these samples were contained in a data package, then samples were chosen to cover the range of concentrations of contaminants detected in the samples from that particular data package.

Reviewers ensured that the data reviewed met the guidelines specified in the USEPA document National Functional Guidelines For Organic Data Review, June, 1991 and Laboratory Data Validation Functional Guidelines For Evaluating Inorganics Analyses(7/88). CDM also reviewed data in accordance with, a Standard Operating Procedures for Validation of CLP Organic Data - USEPA Region V Central Regional Laboratory, August 25, 1993 and Standard Operating Procedures for validation of CLP Inorganic Data - USEPA Region V Central Regional Laboratory September, 1993. In addition, data was compared against further guidelines as specified in the March 1993 SAS Requests for the Southeast Rockford Phase II Remedial Investigation. Data that did not meet these requirements were either rejected completely or accepted with restrictions, and denoted with data qualifiers. Validation criteria that could easily be extended from the 25 percent of the validated data to the non-qualified data, such as laboratory blank contamination, initial calibration, continuing calibration, internal standards and holding times were applied to that data and appropriately flagged. A complete list of the data qualifiers used for validating the Phase II data is provided in Appendix E.

Data that were qualified were specified in each case narrative by the data validator. Validation documentation is available for review in the Southeast Rockford Phase II project files and at USEPA Region V Central Regional Laboratory.

4.1.3 Field Quality Control Samples

4.1.3.1 Introduction

Field quality control samples consisted of trip blanks, field blanks, and field duplicates, and a sample of water used for drilling from the City of Rockford Municipal Source which is the same source as the decontamination water. Trip blanks are used to determine whether sample contamination occurred during sample packaging or shipping. Field blanks serve to reveal possible sample contamination derived from sampling procedures, packaging, or shipping. Field duplicates help to assess the reproductibility of the sampling process and how well the sample represents the environment. The field quality control samples were collected as described in subsection 2.2. The results of the analysis of field quality control samples are provided in Appendix F. Data used for evaluating nature and extent of contamination were qualified based on the results of the field quality control samples as described in Appendix E.

4.1.4 Overall Data Useability Assessment

4.1.4.1 General

Considering the large volume of data collected for Phase II, few analyses were rejected on the basis of laboratory error. This section will discuss the groundwater contaminants which were considered contaminants of concern for the project and any rejected data along with all the soil and air samples and any contaminants which were rejected. The contaminants of concern for groundwater were those contaminants which exceeded or approached the Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCLs). Table 4-1 lists the contaminants of concern.

TABLE 4-1
CONTAMINANTS OF CONCERN

Vinyl chloride	Trichloroethene
Methylene chloride	1,1,2-Trichloroethane
1,1-Dichloroethene	Benzene
1,1-Dichloroethane	Tetrachloroethene
1,2-Dichloroethene (total)	Toluene
1,2-Dichloroethane	Ethylbenzene
1,1,1-Trichloroethane	Xylene
1,2-Dichloropropane	

Contaminants of concern were not chosen for soil samples as the SDWA MCLs are inappropriate to compare with soil samples and there are no comparable standards for soils.

Only a limited amount of data was rejected due to data validation. The base neutral semivolatile groundwater analysis for samples EXT 36 and EXT 36DL for all nondetected parameters were rejected due to low surrogate recoveries. There was also an internal standard problem with EXT 36 and EXT 36DL which resulted in all of the results of this analysis for these two samples to be rejected. Cyanide was rejected in samples MEWJ 67, 68, 69, 70, 71, 72, 73, 74, 75 and 76 due to no recovery of the matrix spike. All endrin results were rejected in samples EXR 61 and EXR 62 due to the poor endrin breakdown and total DDT/endrin breakdown for these samples.

CDM stated in the Phase II QAPP that the CLP is expected to provide data meeting QC acceptance criteria for 95 percent or more of all samples tested. Analytical data from the CLP is assessed for contractual completeness by the Sample Management Office according to their contract compliance screening procedure. CDM reviewed the data for precision, accuracy, and completeness in accordance with the procedures described in the National Functional Guidelines for Organic Data Review published by the USEPA Contract Laboratory Program in Draft form, June, 1991. Data was assessed according to five data quality indicators (DQIs):

Completeness is a measure of the amount of valid data obtained compared to the amount that was expected to be obtained. Field and analytical data may be specified at different completeness levels. The completeness criterion should be defined to be consistent with the project data quality objectives. Completeness will be discussed in Appendix E only if it adversely affects the data.

Comparability is a measure of the confidence associated with comparing one set of data to another. Comparability between Phase II data, and Phase I and Operable Unit data is maintained by employing similar sampling procedures and analytical methods and utilizing appropriate quality assurance and quality control measures. Groundwater sampling was also performed at the same time of year, so seasonal variations would not influence the results. The EPA CLP SOW methods changed slightly from the time of the operable unit to the time of the Phase II investigation. The changes in the CLP SOWs were mainly reporting requirement changes and not analytical procedure changes. Therefore, these changes would not affect the comparability of the data between the different phases of this investigation. The issue of comparability between Operable Unit data, USEPA and IDPH data has been discussed in Southeast Rockford Operable Unit Remedial Investigation Technical Memorandum (September, 1990). It was found that there were often large discrepancies between the residential well sampling results for identical homes. Therefore, this previous residential well data is used only to determine possible historical patterns.

Representativeness is a measure of the degree to which the data represents the actual site, and can serve as a measure of the actual risk at that site. Representativeness is examined by looking at any non-conformance with approved sampling and analytical methodology and evaluation of their effects. During the Phase II field activities, there were few deviations from prescribed sampling and analysis procedures. Any deviation from these procedures are discussed in

Section 2. Also, examination of the results of QC blanks for external sample contamination can be used to evaluate representativeness.

Precision is a measure of the agreement among separate measurements of the same sample. This can be assessed from the duplicate and matrix spike analysis performed on the samples. A number of duplicate samples were collected for each type of matrix and sample analysis performed for the Phase II investigation. A discussion of duplicate results are provided for each sample type in Appendix E.

Accuracy is the degree of agreement of a data point with the true value. All data was analyzed according to USEPA CLP procedures, which included accuracy calculations derived from the percent recovery of spiked samples and the analysis of internal and Performance Evaluation standards. This information was provided in the data packages provided from the laboratory. Accuracy is discussed as needed in Appendix E for each sample matrix and analysis.

4.2 Results of Soil Gas Surveys

Soil gas surveys were conducted during both Phase I and Phase II of the remedial investigation for the Southeast Rockford site. The soil gas surveys were performed to identify areas of soil contamination, and to aid in locating potential contaminant source areas in the study area. As discussed in Section 2, soil gas samples were analyzed for TCA, TCE, and PCE as per the work plan. As discussed in subsection 4.3 of the Technical Memorandum for Phase I Field Activities (CDM, 1992), six areas were selected for soil gas investigation in Phase I. These areas were selected based on the results of groundwater sampling conducted in 1990 during the Operable Unit phase. Based on the results of the Phase I soil gas sampling effort, four of the six areas surveyed were retained for further soil gas investigation in Phase II in order to determine the existence and extent of contaminated soils (Areas 1 through 4; see Figure 4-1); two areas (Areas 5a and 6) were eliminated from consideration as potential source areas. The specific rationale for performing further soil gas sampling in Areas 1 through 4 is as follows:

Area 1 - Wells downgradient contained elevated PCE (545 ppb) and its potential degradation products TCE and cis-1,2-DCE, based on 1990 sampling in the Operable Unit (CDM, 1990). One Phase I soil gas sampling location (sample SG1-28) showed a concentration of a target compound of greater than 1 µg/L (PCE at 4 µg/L). In addition, a laundry facility was noted in the northern portion of this area.

Area 2 - A Phase I soil gas sample contained 120 µg/L PCE, and residential wells roughly downgradient contained PCE and its potential degradation products TCE, cis-1,2-DCE, and vinyl chloride in 1990 samples.

Area 3 - Several Phase I soil gas samples displayed moderate concentrations of PCE, TCE, and TCA (3 to 5 µg/L), and two downgradient residential wells contain elevated PCE.

Area 4 - One Phase I soil gas sample showed high concentrations of TCA and TCE (Phase I sample SG4-10 at 3,400 µg/L of TCA, 180 µg/L TCE) near a metal parts manufacturing facility; one downgradient well had elevated TCA and TCE concentrations in 1990. While the Phase I

CDM
environmental engineers, scientists,
planners, & management consultants

SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY
PHASE II
SOIL GAS SURVEY AREAS

LEGEND:
[Dashed Box] PHASE II SOIL GAS SURVEY AREA
[Dashed Box] AREA 1

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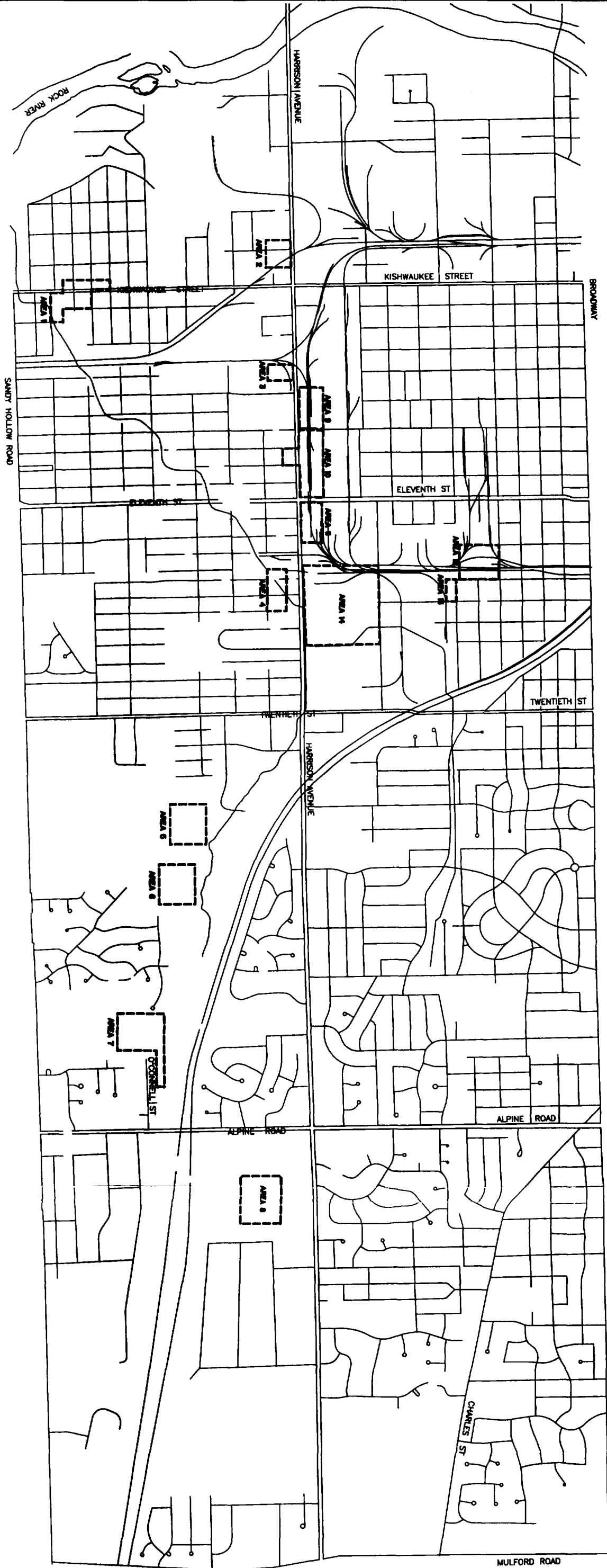
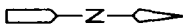


Figure No. 4-1

sample is indicative of a nearby contaminant source, Phase II work was to focus on the extent of this source.

In addition to the above areas, the following areas were identified as potential source areas based on information gathered in Phase I:

Area 5b - Located upgradient (east) of the highest contaminant concentrations detected in Phase I wells (12,000 ppb TCA at MW101B). Aerial photographs from 1958 and 1964 show numerous tracks and areas of possible trenching.

Area 6 - Different from the soil gas Area 6 tested in Phase I, potential source Area 6 is located upgradient of the highest contaminant concentrations detected in Phase I wells (12,000 ppb TCA at MW101B). Based on the presence there of a gravel pit which may have been the location of waste disposal.

Area 7 - Located upgradient (east) of an extensive area of groundwater contamination encompassing MW106 and MW103 (shallow well MW106A had 6,000 ppb TCA), as defined by Phase I sampling. Aerial photos from 1951 through 1970 show evidence of disposal, excavation, and possible trenching. Debris and/or refuse disposal is clearly visible in two small tributary valleys southeast of MW106, and excavation and disturbed ground are present in a larger area east of MW106.

Area 8 - Located upgradient (east) of an area of groundwater contamination by chlorinated solvents near Alpine Road and Harrison Avenue. On-site monitoring wells and RI work conducted at the facility (EDI, 1989) as well as Phase I and II samples show that the contamination originates at this facility.

Of these areas, Phase II soil gas work was conducted at Areas 5a and 7 only. Area 6 was eliminated as a Phase II soil gas survey area after aerial photos of that area became available; these photos showed that the gravel pit only came into existence in the mid-1980s. Area 8 was not considered as a soil gas survey area because of the availability of on-site data showing the likelihood of an on-site contaminant source.

The following additional areas were identified for soil gas investigation during Phase II, based on various lines of evidence developed between Phase I and Phase II:

Area 9 - Located near a low-concentration Phase I soil gas hit in potential source Area 3, and upgradient of a groundwater hit in ISWS well MW46 (302 ppb of TCA, 99 ppb of PCE and 93 ppb of TCE in March 1992).

Area 10 - Located roughly upgradient of ISWS well MW20. Though located in the main portion of the contaminant plume, in past samples MW20 has contained higher contaminant concentrations (426 ppb of 1,1-DCA in March 1992) and different contaminant ratios than those observed in upgradient wells.

Area 11 - Located at an industrial site where oils and chlorinated organic contaminants have been reported from subsurface soils; an on-site monitoring well (MW2 on the railroad right-of-way) contained 1,150 ppb of TCA and 302 ppb TCE in November 1991.

Area 12 - Located at a large facility containing large solvent tanks, which is also suspected because wells roughly downgradient (Unit Well 7, ISWS wells MW1, 2, and 5) have shown high contaminant concentrations in groundwater (generally 50 to 500 ppb of TCE in 1988).

Area 13 - Located at an inactive solvent recovery facility evaluated in a previous IEPA study, where in 1988 on-site monitoring wells contained up to 910 ppb TCA, 620 ppb TCE, and 230 ppb PCE.

Area 14 - Located near the northern margin of the plume, on and adjacent to the former Borg-Warner facility. At the rear of the facility is a chip pit, which may have been unlined for a period of its existence. Soil samples were collected from beneath the chip pit for Borg-Warner by Fehr-Graham & Associates in late 1987 (contaminated soil was apparently removed in 1988); these samples contained up to 1,020 ppm of cis-1,2-DCE, 627 ppm of 1,1-DCA, 150 ppm of TCA, 111 ppm of PCE, and 75 ppm of TCE. Adjacent to (east) of the facility is an area which air photos show had heavy equipment activity from 1958 to 1961, with topsoil and vegetation missing across many small areas where waste disposal may have occurred. A third suspect area is adjacent to the railroad northwest of the facility, where sludge disposal to the ground may have occurred.

The soil gas survey in Area 7 was conducted in two segments. As discussed in Section 1, an initial survey was conducted in May 1992; this survey consisted of 78 soil gas samples collected over an extensive area located roughly upgradient of well nest MW106, focusing on the suspect areas that displayed evidence of disposal and disturbance. While this survey was extensive, it did not completely define the western, northwestern, and southwestern extent of anomalous soil gas concentrations. As a result, additional soil gas work was conducted in Area 7 during February 1993, as part of Phase II. Phase II soil gas work in all other areas was conducted in January and February 1993.

The following discussion summarizes the findings of the soil gas surveys. A more detailed discussion of the Phase I results is found in subsection 4.3 of the Phase I Technical Memorandum (CDM, 1992), and the complete analytical results are found in Appendix A within that document. Complete results for the Phase II soil gas surveys are presented in Appendices G-1 and G-2 of this document.

Area 1

The Phase II soil gas survey in Area 1 centered on an area around Phase I soil gas location SG1-28, which showed 4 µg/L of PCE. Subject to access limitations, samples were placed on centers of approximately 100 feet, and in areas where few samples were collected in Phase I. An additional two samples were placed north of any Phase I samples, at the site of a reported laundry at Barnum Road and Kishwaukee Street. Phase II soil gas sampling yielded three samples with PCE concentrations greater than 1 µg/L, with SG1-3, 1-10, and 1-13 containing 18,

3, and 2 µg/L, respectively. TCA and TCE were not detected above 1 µg/L. Though these concentrations are significant and are consistent with what was observed in Phase I, the sample locations do not constitute a contiguous area of elevated contaminant concentrations. In addition, the moderate magnitude of the concentrations does not indicate a large or particularly concentrated contaminant source in Area 1. Further contaminant source screening work was not undertaken in Phase II, based on the lack of a well-defined suspect area for further work. The shallow unconsolidated deposits consist mainly of sands and some gravel as seen in the boring log for MW119 in Appendix A. The depth to groundwater in this area is about 22 feet. The origin of the elevated contaminant concentrations in the two residential wells is therefore not known.

Area 2

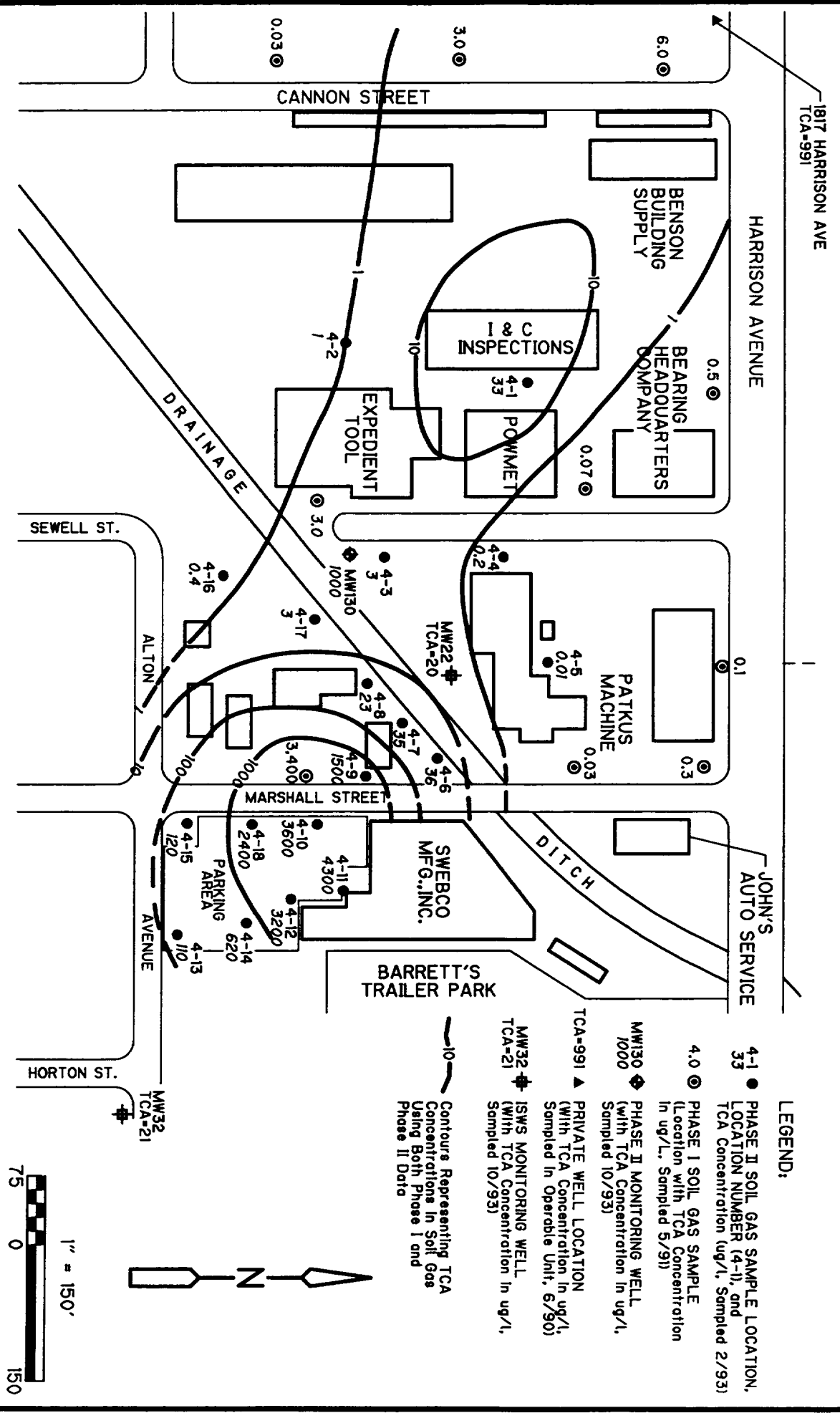
In Area 2, the Phase II soil gas survey area centered on a salvage yard, where a Phase I sample (SG2-9) had a PCE concentration of 120 µg/L. In Phase II, soil gas sampling locations were placed at relatively closely-spaced centers (about 100 feet) around the Phase I hit (elevated contaminant concentration). Phase II results were consistent with Phase I results in showing elevated concentrations for PCE but not for TCE or TCA. The PCE hits comprised four points (SG2-7 through 10) near Phase I point SG2-9, ranging from 2 µg/L to 140 µg/L. Together with Phase I data, these samples constitute an anomalous area of about 150 by 400 feet centered on Kling Street and the salvage yard east of Kling Street. This area may represent a low- or moderate-concentration contaminant source. Based on these results, Area 2 was retained for further investigation as a potential source area; additional source screening work in Phase II consisted of drilling and sampling soil borings as described in subsection 4.5, and sampling upgradient and downgradient monitoring wells as summarized in subsection 4.8. The shallow unconsolidated deposits in this area are also mainly sands with some gravel. Depth to groundwater is about 30 feet in the area.

Area 3

Two soil gas sampling locations were tested during Phase II. These samples were collected west of the Phase I point (SG3-1) that showed elevated results for PCE, TCA, and TCE (5, 4, and 3 µg/L, respectively). The two Phase II samples showed lower but still-detectable concentrations of these compounds (0.2 to 2 µg/L of each target compound). The shallow unconsolidated deposits in this area are mainly sands. Depth to groundwater is about 30 feet. These concentrations were considered to be too low to warrant further source work in Area 3.

Area 4

Phase II soil gas work centered on the area around the highest soil gas concentration detected during the Phase I soil gas survey, which was 3,400 µg/L of TCA at location SG4-10. TCE and PCE concentrations at SG4-10 were 180 and 14 µg/L, respectively. Phase II soil gas samples were collected on centers of about 50 feet near Phase I location SG4-10, and on centers of 100 to 150 feet at greater distances from SG4-10. The Phase II results were consistent with those of Phase I, with high soil gas concentrations of TCA, moderate concentrations of TCE, and low concentrations of PCE. Figure 4-2 shows the results of both the Phase I and Phase II soil gas



SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY

AREA 4 TCA SOIL GAS RESULTS (PHASES I & II)

surveys; on this figure, Phases I and II soil gas results are contoured together because of the consistency in results from the two surveys. Eight Phase II samples contained TCA at greater than 100 µg/L, and five of these samples had concentrations greater than 1,000 µg/L (see Figure 4-2). The core of the high-concentration zone is near the northern end of the parking lot, immediately south of the Swebco Manufacturing building. These soil gas results are consistent with the results of groundwater sampling in the vicinity, which show an anomalous TCA concentration in two wells located approximately 350 feet (MW130) and 1,000 feet (1713 Harrison Avenue) west-northwest (downgradient) of the soil gas hits. In these groundwater samples and in the soil gas samples, the ratio of TCE to TCA is particularly low, being well under 0.10. These ratios contrast with the rest of the groundwater contaminant plume, and with the other soil gas survey areas, and suggest a connection between the Area 4 TCA soil gas hits and the downgradient groundwater TCA detections. Based on the Phase II Area 4 soil gas survey results, further source screening work was performed during Phase II, consisting of drilling and sampling soil borings, and installing a downgradient monitoring well (see subsections 4.5 and 4.8).

In much of the area west and northwest (downgradient) of the Swebco Mfg. parking lot, TCA soil gas concentrations are in the range of 1 µg/L to 50 µg/L. Subsurface soil sampling in this area (at MW130; see subsection 4.5) shows that TCA-contaminated soil was not present in at least part of this area. The low-level TCA hits in this area are possibly a result of volatilization off groundwater that is contaminated near the upper part of the saturated zone; at this level, contaminants are relatively free to volatilize into the unsaturated zone, and travel from there to the depth of soil gas sample collection (generally five feet). Groundwater sampling shows that the shallow portion of the aquifer is contaminated in the vicinity, as MW130 had 1,000 ppb of TCA in Phase II. The shallow unconsolidated deposits are primarily sand and gravel with some silty sand around 5 feet. Depth to groundwater is about 23 feet. Volatilization of the target chlorinated organic compounds from contaminated shallow groundwater likely accounts for the low-concentration TCA hits located west and northwest of the source area at the Swebco Mfg. parking lot.

A second area of elevated soil gas concentrations in Phase II was found at SG4-1. At SG4-1, TCE, TCA, and PCE were present at 66, 33, and 22 µg/L, respectively. Though located downgradient from the contaminant source area at Swebco Manufacturing, the concentrations at SG4-1 appear to be a separate phenomenon. This is based on the fact that the ratios of TCE and PCE to TCA are much higher than those for other soil gas samples in Area 4; as discussed in subsections 4.5 and 4.8, contaminant ratios are useful in determining the relative contribution of potential contaminant sources, as they show coherent results across the soil, soil gas, and groundwater media. At this location, elevated soil gas concentrations are not expected to be a result of volatilization off contaminated groundwater emanating from the source area at Swebco Manufacturing, because soil gas samples collected closer to the Swebco source have lower contaminant concentrations (especially for PCE and TCE); therefore, a local source appears likely near SG4-1. The size and concentration of any potential contaminant source near Phase II location SG4-1 appear to be relatively small, however, based on the lack of elevated TCE or PCE concentrations at nearby soil gas sampling locations. In addition, the soil gas hit at SG4-1 does not appear to influence downgradient groundwater, based on the contaminant ratios at the well

in the northwestern corner of Figure 4-2. At this location, the contaminant ratios are characteristic of those detected in the source area at Swebco Manufacturing. This suggests that the Swebco source is the one that affects groundwater quality, while any source near SG4-1 has only localized influence.

Area 5b

Soil gas work in Area 5b centered on an area that was suspect for two reasons: 1) elevated contaminant concentrations in the Phase I groundwater sample from MW101B (12,000 ppb of TCA), which was considerably higher than samples collected from wells upgradient or downgradient; and 2) aerial photo evidence that shows tracks and areas of possible trenching adjacent to the Northern Illinois Gas above-ground tank facility. Of the seven locations sampled for soil gas, only SG5-4 had contaminant concentrations greater than 1 µg/L (with 6 µg/L of TCA). A concentration of this magnitude could be a result of volatilization of TCA off groundwater originating from Area 7 that is contaminated at shallow depths, or, alternatively, could be due to volatilization from a source in Area 5b. Though an Area 5b contaminant source is possible, such a source would not be large or of high concentration, because no nearby locations had elevated contaminant concentrations in soil gas. Additional evidence against an Area 5b contaminant source is based on Phase II groundwater sampling results, and is presented in the source evaluation section (subsection 4.10).

Area 7

The investigation of a possible source in Area 7 was sparked by the elevated contaminant concentrations in well MW106A. As noted in the Phase I Technical Memorandum (CDM, 1992), a contaminant source was suspected nearby, based on the fact that elevated contaminant concentrations were found only in the shallow well at MW106, while medium and deep wells (MW106B and C) had very low contaminant concentrations. In addition, contaminants were not found in well nests MW108 and 109, located roughly upgradient from MW106. Examination of aerial photographs after Phase I revealed that the area upgradient (east) of MW106 had been the site of various activities since the 1950's. In particular, the 1970 photo shows areas of excavation and disturbed ground in two large areas (Areas 7a and 7b) centered at about 600 and 1300 feet east of MW106 (see Figure 4-3). A third suspect area (Area 7c) consists of several small tributary valleys passing from southeast to northeast of MW106 and as close as 200 feet east of the well nest. In these valleys, debris and unvegetated spots are visible on the 1958, 1964, and 1970 photos. In addition, USEPA received a report of illegal dumping in the past in Area 7.

Based on these lines of evidence suggesting possible contaminant sources in Area 7, a site visit was made by IEPA and USEPA personnel in March 1992. During this visit, surficial evidence of waste disposal (municipal waste such as household appliances and glass, medical waste such as syringes, and assorted rusted drums and paint cans) was discovered and a preliminary terrain conductivity survey was performed. The conductivity survey indicated that buried metals were present at the site. As a result, a more detailed investigation of Area 7 was performed in May 1992. This investigation consisted of a ground-penetrating radar survey conducted by USEPA's Technical Support Section, Office of Superfund, Region 5, a terrain conductivity survey conducted by CDM, and a soil gas survey conducted by Tracer Research Inc. and CDM. A 50-

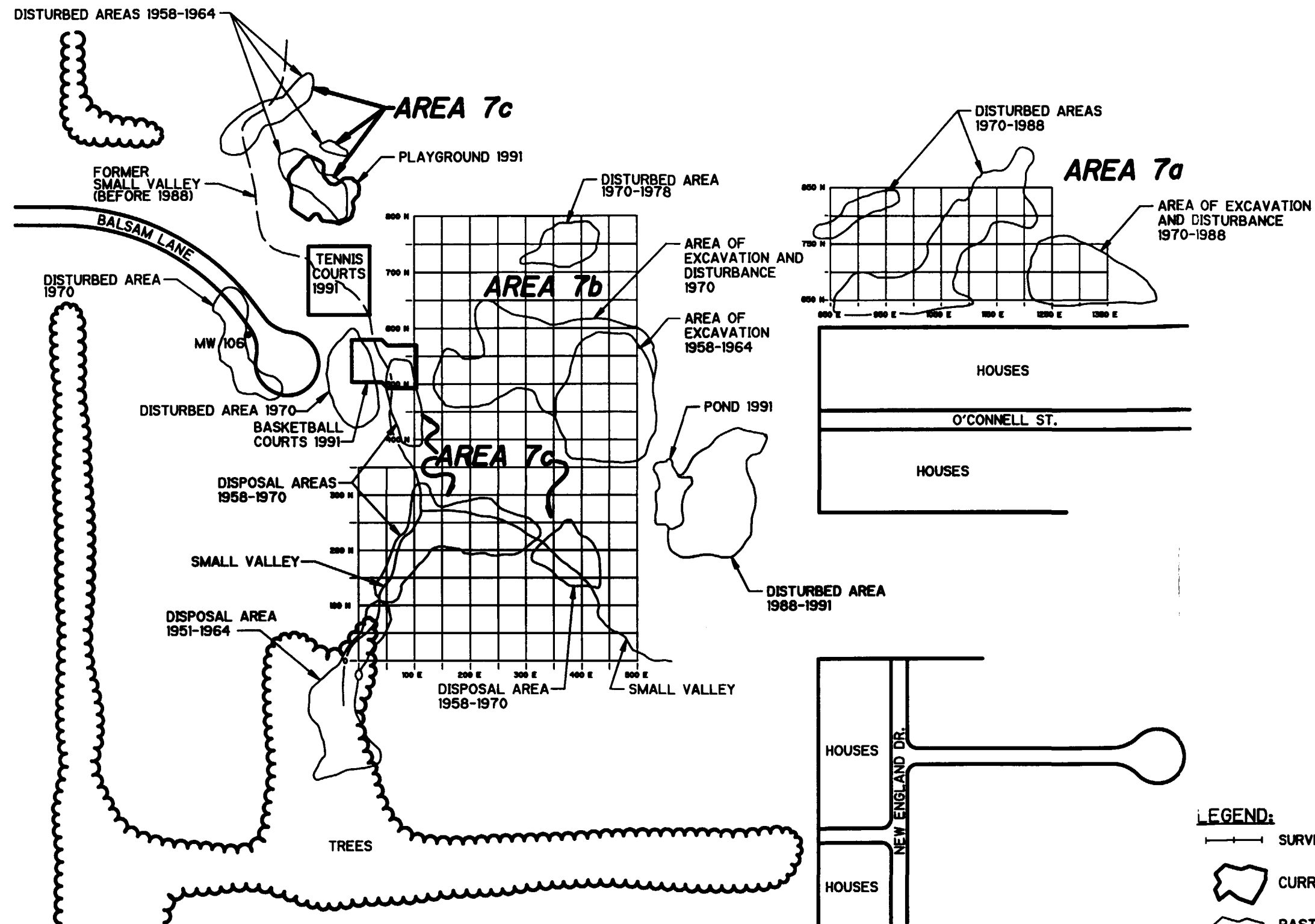
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SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY
POTENTIAL SOURCE AREA 7

CURRENT AND PAST FEATURES, AND SURVEY GRID

foot grid was laid out to cover Areas 7a, 7b, and 7c, and the investigation performed in May 1992 followed this grid. The ground-penetrating radar and terrain conductivity surveys showed similar results, with anomalies present in the Y-shaped set of small valleys of Area 7c. The anomalies range from 25 to 75 feet wide and extend from the south side of the tennis courts, south and southeast toward to the southwestern and southeastern end of the surveyed area (at the 0 north line; see Figure 4-9 in subsection 4.3); the full extent of the anomalous area was not defined by the geophysical surveys.

Soil gas sampling in Area 7 was conducted in two episodes: in May 1992, and in February 1993. The major portion of the work was conducted in May 1992; at this time, 78 soil gas samples were collected across the 50-foot grid across the three suspect areas east of MW106. An extensive area of elevated concentrations of the target compounds was found in soil gas samples collected from Area 7c. As a result, an additional 15 samples were collected in February 1993, to better define the western, northwestern, and southwestern extent of contaminants in soil gas in Area 7c. The north end of Area 7 was not fully characterized by the soil gas effort in Phase II.

The soil gas sampling in Area 7 showed the largest area of soil gas contamination delineated in the RI, as well as some of the highest contaminants detected. In general, the area of soil gas contamination followed the geophysical anomalies defined by the terrain conductivity and ground-penetrating radar surveys: no significant soil gas or geophysical anomalies were detected in the two larger suspect areas east of MW106 (Areas 7a and 7b), but extensive anomalies were detected in each survey in the small valleys closer to MW106 (Area 7c). However, soil gas results differed from the geophysical surveys in two respects: 1) only small soil gas anomalies were detected in the eastern valley of Area 7c located near grid point 200 N, 350 E (see Figure 4-4, which shows the total of TCE, PCE and TCA), while geophysical anomalies were large in this area; and 2) the soil gas anomalies are generally approximately 200 feet wide, considerably wider than the geophysical anomalies, which are generally only about 50 feet wide.

Of the three target compounds (TCA, TCE, and PCE), TCA was generally the most abundant compound detected in Area 7c soil gas samples; this pattern was repeated in the subsurface soil sampling results (see subsection 4.5). As shown in Figure 4-5, in soil gas TCA was detected at elevated concentrations from numerous locations in Area 7c, ranging up to 3,800 µg/L. The highest concentrations were found in a roughly north-south band along the western and northern small valleys. A continuous band of TCA soil gas concentrations greater than 100 µg/L is approximately 200 feet wide and extends about 800 feet from north to south; the total extent of the area with anomalous (greater than 1 µg/L) TCA soil gas concentrations is on the order of 300 by 1,100 feet, though the northern and northwestern perimeter were not completely defined. The Area 7c TCA results clearly indicate that, of the potential source areas surveyed for soil gas contaminants in the RI, Area 7c has the most extensive area with elevated concentrations of the target compounds. Based on these results, Area 7c was selected for further investigation as a potential source; the additional work consisted of test-pit excavation (see subsection 4.3), surface and subsurface soil sampling (see subsections 4.4 and 4.5), and monitoring well installation.

The two suspect areas in Area 7 located east of MW106 (Areas 7a and 7b) showed relatively low contaminant concentrations in soil gas. For Area 7a, the highest soil gas TCA concentration was 1 µg/L; in Area 7b the highest TCA concentration was 4 µg/L. Two samples located between



- NOTE:**

SCALE



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**SUM OF TCA, TCE AND PCE CONCENTRATIONS
IN SOIL GAS -
PHASES I AND II**

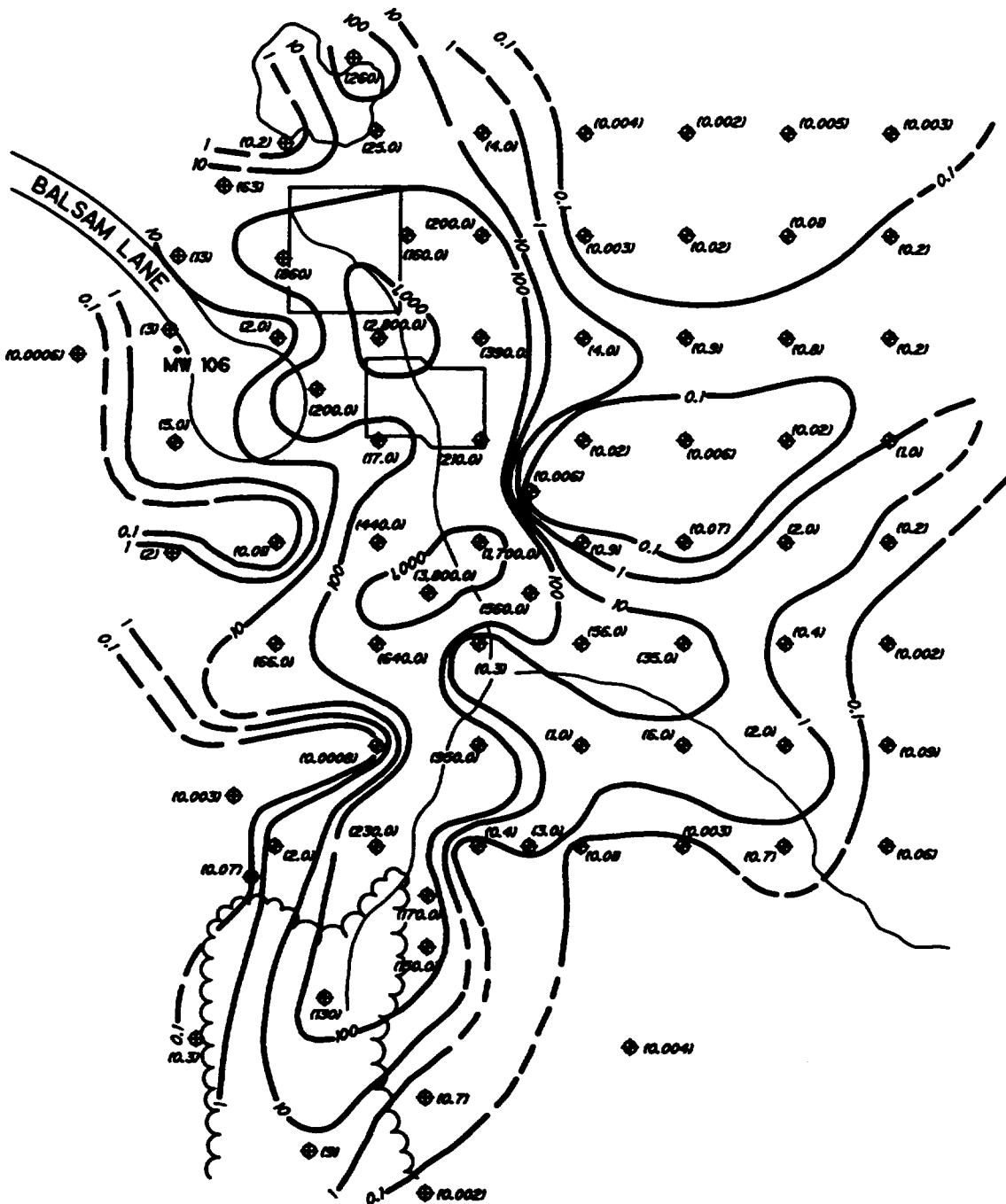
Figure No. 4-4

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FIG4-5

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LEGEND

- ◆ SOIL GAS SAMPLE LOCATION, PHASE I
- ◆ SOIL GAS SAMPLE LOCATION, PHASE II
- 1250.0 TCA CONCENTRATION IN SOIL GAS (ug/L)

NOTE:

CONTOURS ARE BASED ON BOTH PHASE I AND PHASE II RESULTS AND ARE DASHED WHERE INFERRED.

SCALE
50 0 100

SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY
TCA CONCENTRATION IN SOIL GAS -
PHASES I AND II
POTENTIAL SOURCE AREA 7

CDM

environmental engineers, scientists,
planners, & management consultants

Figure No. 4-5

Area 7b and the northern part of Area 7c had considerably higher contaminant concentrations, with 390 and 210 µg/L of TCA. These results clearly show that Areas 7a and 7b are not significant contaminant sources; further source screening work was not performed in these areas.

PCE was the second-most abundant contaminant in most soil gas samples collected from Area 7, and ranged up to 1,100 µg/L. The distribution of PCE in soil gas in Area 7 closely followed that of TCA (compare Figure 4-6 with Figure 4-5). This is illustrated by the fact that across the majority of Area 7c, the ratio of PCE to TCA is mainly in the range of 0.05 to 0.35. The exception to this pattern is in the southern portion of Area 7c, where PCE to TCA ratios are in the range of about 1.0 to 3.0. In Area 7a, the highest PCE concentration in soil gas was 1 µg/L. In Area 7b, the highest PCE soil gas concentration was 2 µg/L. However, samples with higher PCE concentrations in soil gas were just southeast (8 µg/L) and west (98 and 16 µg/L) of Area 7b. As with TCA, the latter two samples were from between Areas 7b and 7c.

TCE was the least abundant of the three target compounds analyzed for in the soil gas survey for Area 7, and was detected at concentrations ranging up to 690 µg/L (see Figure 4-7). The distribution of TCE closely followed that of both TCA and PCE, with the most abundant contamination occurring in the small valleys of Area 7c. This is illustrated by the fact that the ratio of TCE to TCA in soil gas samples in Area 7c was relatively constant, ranging from 0.1 to 0.3; the exception to this pattern is in the samples near the tennis and basketball courts, where this ratio ranges from 0.005 to 0.07. This localized pattern of low TCE concentrations relative to TCA is paralleled by the groundwater contamination patterns (discussed in subsection 4.8): at MW106A just downgradient from the basketball courts, the TCE to TCA ratio is less than 0.04 (TCE was not detected at MW106A), while nearly all other wells in the same contaminant plume have TCE to TCA ratios ranging from 0.15 to 0.45. This concordance lends further credibility to the soil gas sampling results, and to the idea of using contaminant ratios in determining potential sources for contaminants in the groundwater.

Similar to the patterns of TCA and PCE in soil gas samples from Areas 7a and 7b, no elevated TCE concentrations were found in either area; the only significant sample results were found from two samples between Areas 7b and 7c, where TCA was detected at 26 and 1 µg/L.

Area 9

Soil gas work in Area 9 centered on an area near a low-concentration Phase I soil gas hit in potential source Area 3 (at SG3-1), and upgradient of a groundwater hit in ISWS well MW46 (302 ppb of TCA, 99 ppb of PCE, and 93 ppb of TCE in March 1992). Two of the six Phase II soil gas samples collected from Area 9 contained target compound concentrations greater than 1 µg/L. Samples SG9-4 and 9-5 contained elevated concentrations of the three target compounds in roughly similar proportions: in SG9-4, TCA, PCE, and TCE were detected at 120, 120, and 91 µg/L, respectively, while SG9-5 contained 18, 24, and 7 µg/L, respectively, of the same compounds. These results are also concordant with Phase I soil gas sample SG3-1. Owing to difficulty of access and lack of access to properties located east of location SG9-4, soil gas concentrations were not closed off to the east; it is possible that soil gas contaminant concentrations are higher to the east, and that a potential source area may lie to the east. Based on the elevated contaminant concentrations in Phase II soil gas samples, Area 9 was retained for

B. SELIGA, MIW-CHI.

06/02/94 0103109

FIG 4-6

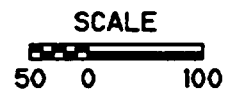
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LEGEND

- ◆ SOIL GAS SAMPLE LOCATION, PHASE I (MAY 1992)
- ◆ SOIL GAS SAMPLE LOCATION, PHASE II (FEB. 1993)
- 1750.0 PCE CONCENTRATION IN SOIL GAS (ug/L)

NOTE:

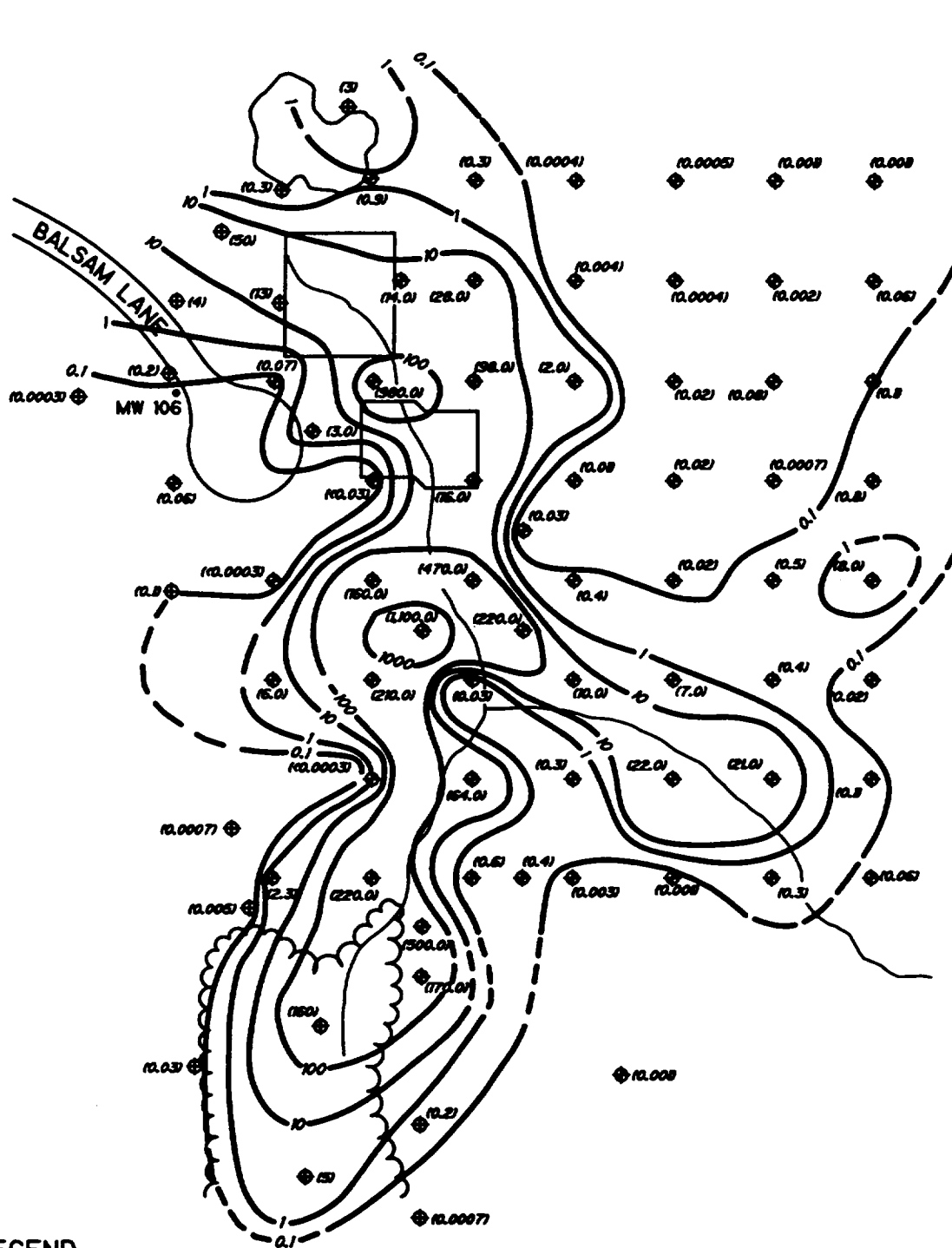
CONTOURS ARE BASED ON BOTH PHASE I & PHASE II RESULTS & ARE DASHED WHERE INFERRED.

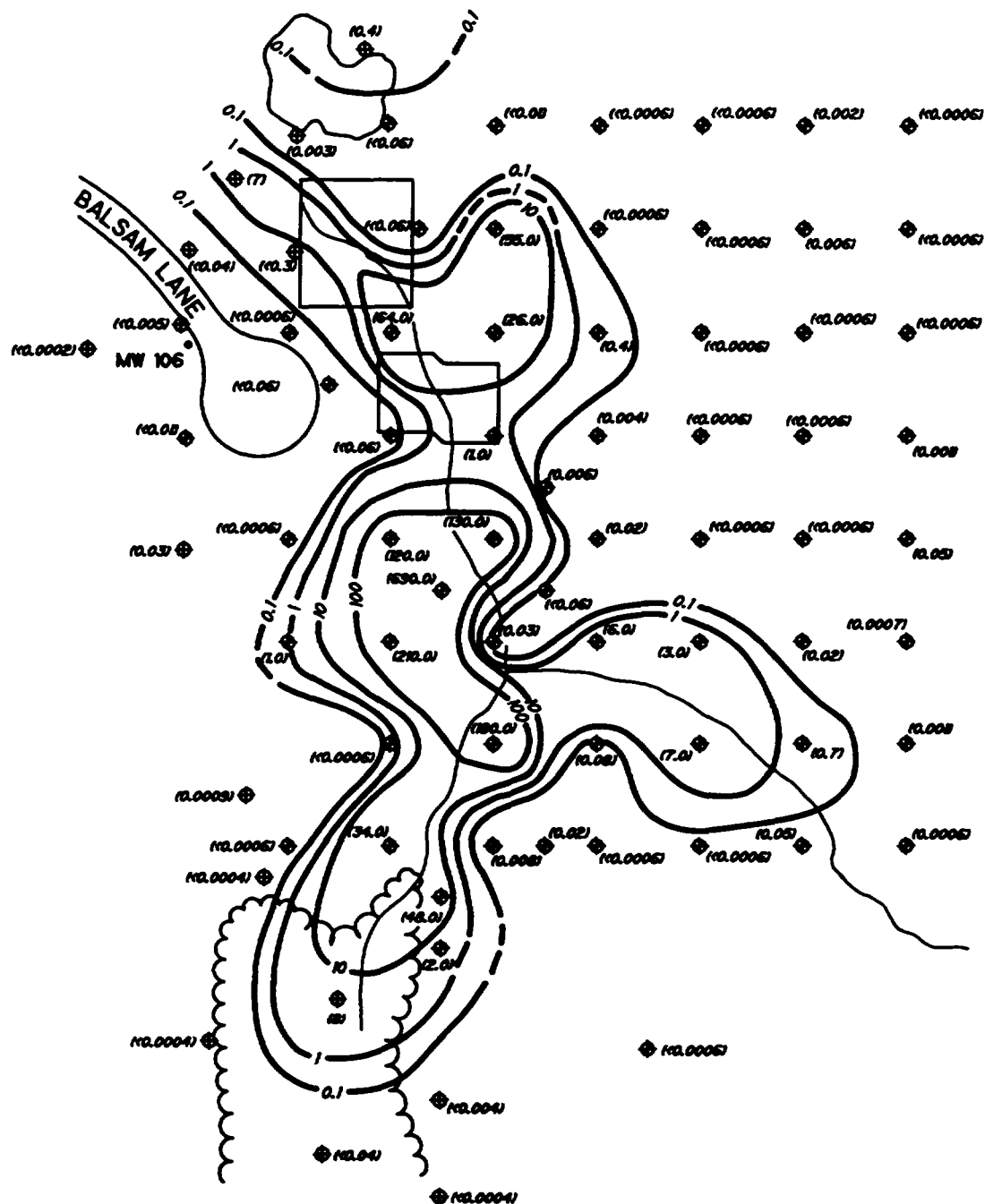


SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY
PCE CONCENTRATION IN SOIL GAS -
PHASES I AND II
POTENTIAL SOURCE AREA 7

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Figure No. 4-6





further source screening in Phase II. The additional work consisted of subsurface soil sampling near location SG9-4 and downgradient monitoring well installation (MW125 and MW126 nest).

Area 10

Soil gas work in Area 10 centered on two areas roughly upgradient of ISWS well MW20. Though located in the main portion of the contaminant plume, in the past MW20 has shown higher contaminant concentrations (426 ppb of 1,1-DCA in March 1992) and different contaminant ratios than observed in wells upgradient. Two soil gas samples in Area 10 had contaminant concentrations above 1 µg/L: SG10-11 had 3 µg/L of TCA, and SG10-14 had 2 µg/L of TCA. TCE and PCE were not detected at concentrations above 1 µg/L in any samples from Area 10. The elevated contaminant concentrations in soil gas samples from the portion of Area 10 that was investigated, are not either high enough or clustered together in a way consistent with the idea of a nearby contaminant source. However, as discussed in subsection 4.10, a contaminant source is still possible in another portion of Area 10, along Harrison Avenue on the block east of Ninth Street (a portion of Area 10 where access was not acquired). In addition, the existence of elevated TCA at location SG10-14 may suggest a contaminant source located west of Ninth Street (in Area 9, west of Area 10), a short distance north of Harrison Avenue. As noted in the above discussion on Area 9, this portion of Area 9 was another area not accessible for soil gas work.

Area 11

Soil gas work in Area 11 centered on an industrial site where oils and chlorinated organic compounds have been reported from subsurface soil samples. An on-site monitoring well had 1,150 ppb TCA and 302 ppb TCE in a sample collected in November 1991. In addition, Area 11 is roughly upgradient of well MW20. As noted above under Area 10, MW20 has higher contaminant concentrations and different contaminant ratios than in wells upgradient, suggesting a possible contaminant source nearby, such as in Areas 10 or 11. Only one of the five soil gas samples collected from Area 11 contained a target compound at a concentration of 1 µg/L or greater: SG11-5 had 1 µg/L of PCE. The full significance of this detection is not known, because it was the southwestern-most sample collected. It is possible that PCE may be present at higher concentrations to the west or south from location SG11-5. However, any such PCE concentrations do not appear to significantly affect downgradient groundwater, because wells MW20 and MW127 (located roughly downgradient) do not contain elevated concentrations of this contaminant.

The soil gas work in Area 11 comprised sampling from only the southwestern portion of Area 11. At the time of the soil gas survey, access was not yet acquired for the northern and eastern parts of Area 11, including the area of the on-site monitoring well noted above. As a result, Area 11 was retained for further screening as a potential source area. Additional work performed in Phase II consisted of subsurface soil sampling and monitoring well installation.

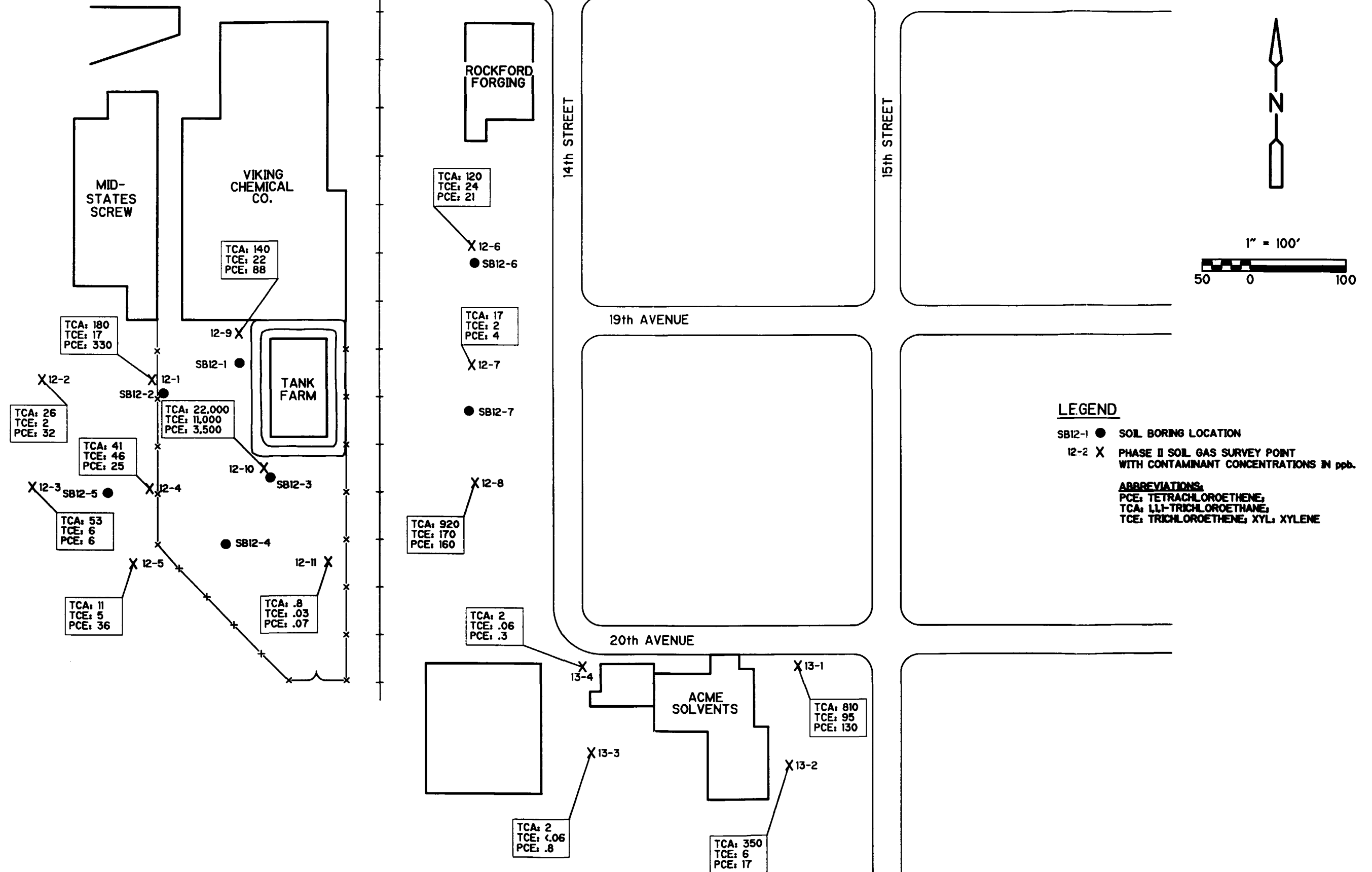
Area 12

Soil gas work in Area 12 centered on the area around an extensive above-ground tank farm, which includes tanks containing chlorinated solvents. Area 12 is also suspected because wells roughly downgradient (Unit Well 7, ISWS wells MW1, 2, and 5) have shown high contaminant concentrations in groundwater (generally 50 to 500 ppb of TCE in 1988). Ten of the 11 soil gas samples collected in Area 12 contained concentrations of the target compounds of greater than 1 µg/L. The results of soil gas sampling are shown in Figure 4-8. The sample SG12-10 had the highest concentrations of any soil gas samples collected in Phase I or Phase II of the RI. Contaminant concentrations at this location were 22,000 µg/L for TCA, 11,000 µg/L for TCE, and 3,500 µg/L for PCE. Away from sample SG12-10, however, soil gas contaminant concentrations decline rapidly, with no other sample attaining a concentration as high as 10% of those reported from SG12-10.

As in other areas (Areas 4, 7, and 13), soil gas contaminant concentrations in the general range of 100 to 1,000 µg/L appear to be characteristic of areas where a target contaminant source is present in the subsurface, but at some distance (about 50 feet or more) away. Soil gas contaminant concentrations exceeding about 1,000 µg/L typically indicate areas where high levels of contaminants are present a short distance below or adjacent to the soil gas sampling location, based on subsurface soil sampling (see subsection 4.5). The soil gas concentration patterns in Area 12 suggest that a subsurface contaminant source is present in Area 12, and that it may have a limited areal distribution. Based on the soil gas survey results, Area 12 was retained for further screening as a potential source area. The additional work conducted in Phase II consisted of monitoring well installation and subsurface soil sampling.

Area 13

Soil gas work in Area 13 centered on an area with known contamination of the target compounds in subsurface soils. Based on an IEPA investigation performed in 1988, the area with part per thousand level VOC contamination in the subsurface soils is primarily beneath the former Acme Solvents building. The purpose of the soil gas sampling in Phase II was to determine whether the contaminant source area extends beyond the approximate extent of the former Acme Solvents building. All four soil gas samples collected from Area 13 contained concentrations of at least one target compound (TCA) of greater than 1 µg/L (see Figure 4-8). The highest concentrations were found in samples SG13-1 and 13-2, where TCA was detected at 810 and 350 µg/L, respectively. PCE and TCE were detected at considerably lower concentrations at all locations. Locations SG13-1 and 13-2 are located nearest the area of known subsurface contamination (30 to 40 feet from the building); the moderate contaminant concentrations at these locations (between 100 and 1,000 µg/L) suggest that the subsurface contaminant source does not extend nearly that far east from the building. Samples SG13-3 and 13-4 are located about 120 to 150 feet west of the building, and each has TCA concentrations of 2 µg/L. The shallow unconsolidated deposits in this area are primarily sand and gravel. Depth to groundwater is approximately 30 feet. A possible explanation for the low-level concentrations of samples SG13-3 and 13-4 is volatilization of contaminants upward from groundwater that is contaminated near the water table; these relatively low concentrations also appear to indicate



SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY

POTENTIAL SOURCE AREA 12 AND 13 SOIL BORING SAMPLING LOCATIONS AND SOIL GAS SAMPLING RESULTS

that the contaminant source beneath the Acme Solvents building does not extend more than a short distance west of the building. Additional source screening was not performed during Phase II in Area 13.

Area 14

The soil gas survey in Area 14 centered on three potential source areas: 1) a former chip pit location, where waste metal trimmings were stored and where underlying soils contained high concentrations of the target compounds (150 ppm of TCA, 111 ppm of PCE, and 75 ppm of TCE) and other chlorinated organics; 2) a field east of the facility where aerial photos show potential disposal from 1958 to 1961; and 3) an area north of the chip pit and adjacent to railroad tracks where disposal may have occurred. The soil gas survey was completed after the removal of contaminated soils from the chip pit, which apparently occurred in late 1987 or in 1988.

Of the three suspect areas, no significant soil gas concentrations (i.e., greater than 1 µg/L) of target compounds were detected in the second or third area listed above. Near the chip pit, however, TCA, TCE, and PCE were each detected at concentrations greater than 1 µg/L at eight, three, and two sampling locations, respectively. These locations are all east and south of the chip pit, and most are within about 75 feet of the chip pit. The highest concentrations of TCA were 16 and 13 µg/L, at locations SG14-52 and 14-51, respectively. The other five anomalous TCA sample results ranged from 2 to 7 µg/L. The anomalous TCE concentrations ranged from 2 to 4 µg/L, and the anomalous PCE concentrations were both at 1 µg/L. Owing to the relatively high number of samples with contaminant concentrations above 1 µg/L and based on the high historical contaminant concentrations in soils, additional source screening work was conducted in Area 14. The additional work consisted of subsurface soil sampling and monitoring well installation.

4.3 Results of Test Pit Sampling

Test pit excavation and sampling was conducted in Area 7 to characterize the anomalies found during the soil gas and geophysical surveys. Test pit excavation was performed in place of subsurface borings because it would allow better visualization of subsurface metallic objects whose presence was suggested by geophysical surveys. Exposure of this material could give evidence as to the origin of any disposed material (labels, drums, containers, etc.) that might be present in the area. Test pit excavation and the accompanying soil and air sampling was conducted in Area 7 from June 15 through June 17, 1993 using the methods discussed in subsection 2.4. Test pit locations are shown in Figure 4-9. Test pit 1 (TP-1), the southern excavation, was located in an area of geophysical anomalies but no soil gas anomalies. Test pit 2 (TP-2), the northern excavation, was located in order to characterize an area with both geophysical and soil gas anomalies. Test pit dimensions measured 10 feet by 10 feet by 15 feet. The excavations revealed the presence of glass bottles, metal cans, other metal objects, and miscellaneous trash. The subsurface soil material in TP-1 consisted of moist brown silt and sand; in TP-2 the subsurface material consisted of both brown sand and moist, gray-stained, odoriferous sand.

SOURCE AREA 7 TEST PIT LOCATIONS

To screen for the presence of hydrogen cyanide, hydrogen sulfide, and VOCs, soil borings were advanced at the test pit locations prior to the excavation. A total of eight soil borings were advanced, four at each excavation area at the perimeter of the test pits. Split-spoon samples were collected every two feet until a total depth of 15 feet was reached. The samples were screened for hydrogen cyanide, hydrogen sulfide, and organic vapors, and the results are presented in Table 2-2. While high levels of organic vapors were detected in test pit 2 (up to 220 ppm in soil borings 1 and 2), there were no organic vapor readings exceeding 3 ppm for test pit 1. No hydrogen sulfide or hydrogen cyanide vapors were detected in the soil borings surrounding either test pit 1 or test pit 2.

4.3.1 Results of Test Pit Soil Sampling in Area 7

Soil samples were collected from the walls and bottoms of the test pits, and selected by visual, odor, and organic vapor analysis screening. Soil samples were analyzed for high-concentration Target Compound List (TCL) organics, high-concentration Total Analytes List (TAL) inorganics, and Toxicity Characteristic Leaching Procedure (TCLP) organic and inorganic parameters. The full results for test pit soil samples are presented in Appendix H-1.

Four high-concentration TCL and TAL soil samples were collected from each test pit (one duplicate was collected from test pit 2). Methylene chloride and PCE were the only compounds detected in test pit 1. The following contaminants were detected in test pit 2: methylene chloride, acetone, 1,2-DCE (total), TCA, TCE, PCE, and xylene. All methylene chloride and acetone detections were qualified as "B", indicating that the compounds were detected in the blank. The quantity detected ranged up to 10 ppm for methylene chloride and 6 ppm for acetone, indicating that the result may be due to laboratory contamination. Methylene chloride and acetone contamination will therefore not be discussed further. TP1-SS3 was the only soil sample from test pit 1 to indicate contamination. The sample was collected 2 feet west of the pit center at an approximate depth of 4 feet, where PCE was the only compound detected, at 0.5 ppm.

Samples from test pit 2 indicated greater contamination by VOCs. Sample TP2-SS3, collected 2 feet south of the pit center and at a depth of approximately 6 feet, contained 22 ppm PCE, 4 ppm TCA, and 3 ppm TCE. PCE, 1,2-DCE(total), TCA, and xylene were detected in one or two additional test pit 2 samples, at concentrations ranging from 1 to 3 ppm in TP2-SS4, TP2-SS5, or TP2-SS6.

The only semivolatile compound detected in the TCL soil samples was bis(2-ethylhexyl)phthalate at 2 ppm in TP2-SS3. This compound is a common plasticizer and a common laboratory and sampling contaminant.

In the high-concentration TAL soil samples, inorganic analytes were detected at concentrations above national averages in test pit 2, but not in test pit 1 (see Shacklette & Boerngen, 1984). Copper, iron, lead, mercury, nickel, vanadium, and zinc were detected at concentrations above these averages in samples from test pit 2. These elevated concentrations were detected in the duplicate sample (D) of TP2-SS3 (none of the substances in the original sample exceeded national averages), TP2-SS4, and TP2-SS6. TP2-SS3(D) was the only sample in which mercury was

detected, at 1.3 ppm. Sample TP2-SS4, collected at the pit center at an approximate depth of 10 feet, indicated copper contamination at 734 ppm, and zinc contamination at 711 ppm. TP2-SS6, collected on the east pit wall at an approximate depth of 7 feet, had the highest detected concentrations of iron, at 49,100 ppm, lead at 507 ppm, and zinc at 1,020 ppm. This was also the only sample where vanadium and iron were detected at concentrations above the national average.

TCLP organic analysis for selected volatile and semivolatile compounds was performed only for two samples per test pit (and a duplicate sample from test pit 2). TCLP analysis was performed in order to assess the potential for contaminants to migrate away from source soils. The analysis is designed to determine whether or not a sample (solid waste) exhibits the characteristic of toxicity. Certain contaminants have a set regulatory level which, if exceeded, indicates that a solid waste is toxic. Methylene chloride was detected in all samples, at concentrations ranging from 55 to 70 ppb. TCA was detected in TP2-SS1 (collected 5 feet east of the pit center at an approximate depth of 15 feet), and in its duplicate at 1,300 and 960 ppb. TCE was detected in the test pit 2 samples, at 1,100 ppb in TP2-SS1 (and 940 ppb for its duplicate), and at 44 ppb in TP2-SS2, collected at pit center at an approximate depth of 10 feet. PCE was detected at 3,200 ppb in TP2-SS1 (and 3,100 ppb for its duplicate), and at 340 ppb in TP2-SS2. Toluene was detected in TP2-SS1 and its duplicate at 260 and 230 ppb. This was also the only compound (besides methylene chloride) to be detected in test pit 1, at 24 and 32 ppb in samples TP1-SS1, and TP1-SS2. TP1-SS1 was collected 2 feet west of the pit center at an approximate depth of 4 feet, and TP1-SS2 was collected in the pit center at an approximate depth of 9 feet. The only semivolatile compound detected in TCLP analysis was 1,2-dichlorobenzene, detected in TP2-SS1 and its duplicate at 56 and 65 ppb. Sources of TCA, TCE, and PCE have already been discussed. Toluene is a commonly used industrial solvent for paints, coatings, resins, and rubber compounds. Methylene chloride is used to clean, degrease, and dry metal parts. It is also used as a paint and varnish remover.

TCLP inorganic analysis yielded primarily non-detects, except for barium and chromium. Barium was detected in every compound at concentrations ranging from 264 to 974 ppb, but all qualified with a "B", indicating blank contamination. Chromium was detected in TP1-SS2 at 92.9 ppb, also qualified with "B".

Of the compounds detected in TCLP analysis, methylene chloride, TCA, toluene, and 1,2-dichlorobenzene do not have TCLP regulatory levels. Barium and chromium each have a regulatory level of 5 ppm (5,000 ppb), which was not exceeded by any test pit sample. The regulatory level for TCE is 0.5 ppm (500 ppb). One sample collected from test pit 2 (TP2-SS1 and its duplicate) exceeded this value at 1,100 ppb (940 ppb for the duplicate). The regulatory level for PCE is 0.7 ppm (700 ppb). The same sample collected from test pit 2 exceeded this value at 3,200 ppb (3,100 ppb for the duplicate).

4.3.2 Results of Test Pit Air Sampling in Area 7

Ambient air samples in the breathing zone were collected during the test pit excavation in order to provide information relating to health risks under a future construction scenario. The full results for test pit air samples are presented in Appendix H-2. Real-time monitoring was also

conducted with an OVA to indicate current VOC concentrations during the excavation. This monitoring was performed primarily to ensure the safety of on-site personnel and safety of nearby residents.

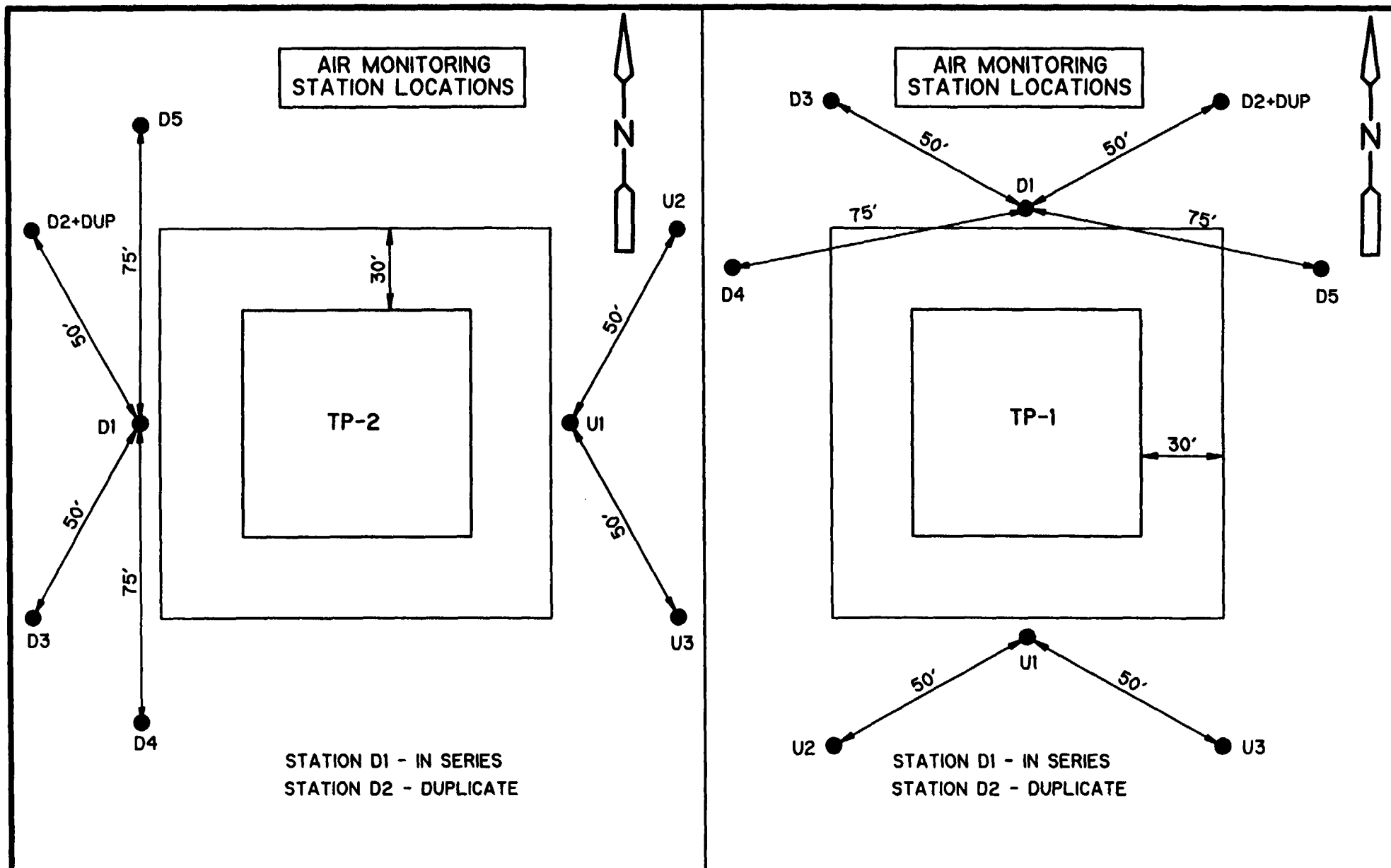
Eleven air samples were collected from each test pit, including one duplicate sample, one blank, and one collected as the second sample in a series of two tubes, at each pit. These sampling locations are detailed in Figure 4-10. Three of the samples were collected upwind of the excavation (at three locations), and seven samples were collected downwind (at five locations) using Tenax tubes connected to a personal sampling pump. Three samples were spiked at the laboratory for certain compounds; therefore, quantitative analytical results for these compounds in these samples are not as reliable as those for unspiked samples. One of these samples was the field blank for test pit 1. Methylene chloride was detected in three test pit 2 samples (plus the laboratory blank), in concentrations ranging from 8 to 79 nanograms of compound per total mass of Tenax in tube (ng/OC). Acetone was detected in six test pit 2 samples, at concentrations ranging from 27 to 49 ng/OC. All methylene chloride and acetone results were qualified with a "B", indicating blank contamination may be the cause. Methylene chloride and acetone contamination will therefore not be discussed further.

The field blank associated with test pit 1 was spiked by the laboratory with undocumented quantities of the spike compounds. Based on their reported spike recoveries (ranging from 80 to 123 percent) it is likely that the field blank was fairly clean before spiking, however there is no way to know this. Therefore, the field blank for test pit 1 is considered unusable. The three upwind samples for test pit 1 contained only TCA, carbon tetrachloride, benzene, PCE, 1,1,2,2-tetrachloroethane, and toluene (in one, two, or all three samples) at concentrations no higher than 12 ng/OC, with the exception of 1,1,2,2-tetrachloroethane detected in TP1-108-U1 at 25 ng/OC and toluene detected in TP1-408-U3 at 44 ng/OC (see Figure 4-10 for locations).

The downwind samples from test pit 1 were found to contain 1,2-DCE (total), TCA, carbon tetrachloride, TCE, benzene, PCE, toluene, ethylbenzene, and xylene (total). In general, these compounds were not detected at significantly higher concentrations than those detected in the upwind samples, with the exception of sample TP1-120-03, to be discussed below. The compounds 1,1-DCA, 1,2-DCA, 1,1,2-TCA, 4-methyl-2-pentanone, and PCE were also detected in TP1-193-01(2) (collected 20 feet south of the test pit), but they had been spiked to the sample, and were detected at concentrations ranging from 98 to 120 ng/OC, not significantly higher than the amount spiked on the sample, 100 ng/OC.

Downwind sample TP1-193-01(2) was collected in series with TP1-179-01(1). Most compounds detected in TP1-193-01(2) were detected at 110 and 120 ng/OC, not significantly higher than the added spike. Carbon tetrachloride, which was not added as a spike, was detected in TP1-193-01(2) at 4 ng/OC. The only compounds detected in TP1-179-01(1) were TCE, benzene, toluene, and ethylbenzene, at concentrations less than 20 ng/OC. Due to the spiking of TP1-193-01(2), calculation of the percent breakthrough was not possible.

Downwind sample TP1-150-02 (and its duplicate), TP1-125-04, and TP1-409-05 were contaminated at various degrees with the compounds listed above at concentrations below 15 ng/OC. TP1-120-03, collected southeast of the test pit, indicated contamination with 1,2-DCE



SOUTHEAST GROUNDWATER CONTAMINATION STUDY

SOURCE AIR 7 TEST PIT
AIR SAMPLE LOCATIONS**CDM**environmental engineers, scientists,
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Figure No. 4-10

(total) (30 ng/OC), TCA (97 ng/OC), TCE (41 ng/OC), benzene (15 ng/OC), PCE (30 ng/OC), toluene (19 ng/OC), and ethylbenzene (3 ng/OC).

The three samples collected upwind of test pit 2 had 1,2-DCE (total), 2-butanone, TCA, carbon tetrachloride, TCE, benzene, PCE, toluene, ethylbenzene. The compounds 1,2-DCE (total) and ethylbenzene were detected only in one sample, TP2-182-U1, at 3 ng/OC. This sample was collected in the worksite exclusion zone, approximately 20 feet from the east wall of the pit. TP2-182-U1 also had TCE at 11 ng/OC, 57 ng/OC TCA, and 35 ng/OC PCE (but qualified as "B"). The PCE detection is considered valid as it is greater than 5 times the laboratory blank concentration of 6 ppb. Detections of the other compounds in the other two samples were lower, with none exceeding 21 ng/OC. These samples were collected approximately 50 feet northeast and southeast from TP2-182-U1. Compounds detected at some concentration in all three upwind samples were TCA, carbon tetrachloride, benzene, and toluene.

Contamination was detected in all six samples collected downwind of test pit 2 (plus one duplicate). The same compounds detected in the upwind samples were detected in the downwind samples, with the addition of 1,1-DCE, 1,1-DCA, and xylene (total). In general, compounds downwind of the test pit were detected at higher concentrations than in the samples upwind of the test pit. However, 2-butanone, carbon tetrachloride, benzene were detected at approximately the same concentrations downwind as upwind. The compounds 1,2-DCA, 1,1,2-TCA, 4-methyl-2-pentanone, and PCE were also detected in TP2-103-05, but they had been spiked to the sample, and were detected at concentrations ranging from 86 to 110 ng/OC, not significantly higher than the amount spiked on the sample, 100 ng/OC.

Downwind samples TP2-199-01(1) and TP2-70-01(2) were collected in series for the purpose of determining if excessive contaminant concentration would result in saturation and breakthrough of the sample tubes. The samples were collected approximately 20 feet from the western edge of test pit 2. TP2-70-01(2) was the sampling tube where the sample would first be adsorbed, and therefore would be expected to represent the truest sample concentration. In this sample, high concentrations of PCE (2100 ng/OC, qualified "B"), TCA (2000 ng/OC), TCE (840 ng/OC), 1,2-DCE (total) (290 ng/OC), and xylene (210 ng/OC, qualified "B") were detected. Other compounds detected include toluene (53 ng/OC, qualified "B"), ethylbenzene (39 ng/OC), and benzene, 1,1-DCA, and 1,1-DCE (all detected at less than 20 ng/OC). The concentrations reported in the second tube in the series, TP2-199-01(1) tended to be approximately one-quarter of those reported for TP2-70-01(2). Backup cartridges should contain less than 20% of the concentrations detected in the front cartridge according to EPA Method TO-1, so the quantitation of these samples is likely biased low due to breakthrough of the contaminants.

Downwind sample TP2-178-02 and its duplicate, TP2-403-02, also contained high concentrations of PCE (2500 and 2600 ng/OC, qualified "B"), TCA (2400 and 2300 ng/OC), TCE (1100 and 1200 ng/OC), 1,2-DCE (total) (380 and 390 ng/OC), and xylene (total) (260 and 270 ng/OC, qualified "B"). Other compounds detected include toluene (97 and 1000 ng/OC, qualified with "B"; the reason for the discrepancy in values is unknown), ethylbenzene (47 and 48 ng/OC), 1,1-DCA (26 ng/OC in both samples), and 1,1-DCE, carbon tetrachloride, and benzene (all detected at less than 20 ng/OC). These samples were collected northwest of TP2-199-01(1) and TP2-70-01(2).

Downwind samples TP2-151-03, and TP2-400-04, collected southwest of the test pit, did not have any compounds detected at greater than 50 ng/OC, with the exception of toluene, detected at 51 and 520 ng/OC, respectively, and qualified with "B". TCA was detected in these samples at 47 and 31 ng/OC respectively; all other compounds were detected at values less than 20 ng/OC. Sample TP2-103-05, collected approximately 75 feet north of TP2-199-01(1) and TP2-70-01(2), was spiked by the lab, so accurate sample quantitation is not possible for all compounds. However, PCE and TCA were reported at concentrations of 900 and 800 ng/OC respectively, significantly higher than the 100 ng/OC spike, so their presence in the investigative sample can be assumed. Similarly, TCE (330 ng/OC), xylene (260 ng/OC, qualified "B"), 1,2-DCE (total) (190 ng/OC), and toluene (180 ng/OC) were all detected at concentrations at least 20% greater than the amount spiked, indicating their likely presence in the investigative sample.

4.3.3 Summary of Test Pit Soil and Air Sampling Results

Test pit 1 soils/wastes contained relatively low concentrations of the contaminants of concern. It is important to note that due to the expected nature of the samples, they were analysed by high concentration methods with detection limits of 2.5 parts per million (ppm). It is possible that contaminants of concern are present below the ppm levels. PCE contamination at 0.5 ppm was detected in one sample. TCLP analysis for volatiles indicated contamination with toluene at concentrations up to 32 ppb. No semivolatile contamination was detected, and no inorganic analytes were detected at concentrations above national averages for near-surface soils.

The upwind air samples from test pit 1 showed relatively low contaminant concentrations, except for single detections of toluene at 44 ng/OC and 1,1,2,2-tetrachloroethane at 25 ng/OC. Only one downwind air sample from test pit 1, TP1-120-03, displayed levels of contaminants above 20 ng/OC. This sample was contaminated with 1,2-DCE (total), TCA, TCE, and PCE at concentrations ranging from 30 to 97 ng/OC. These results are consistent with the relatively low contaminant concentrations present in test pit 1 soils.

Test pit 2 soils exhibited considerably higher contamination with VOCs, with PCE present at up to 22 ppm and TCA up to 4 ppm. TCLP analysis for volatiles indicated contamination with TCA, PCE, and toluene. The only semivolatile contaminant detected was a single detection of bis(2-ethylhexyl)phthalate at 2 ppm. Inorganic analytes including mercury and various heavy metals were detected at concentrations above national averages for soils.

The upwind air samples from test pit 2 contained relatively low contaminant concentrations, except for the detection of 57 ng/OC TCA and 35 ng/OC PCE in TP2-182-U1. As might be expected based on test pit soil samples, considerably higher contaminant concentrations were detected in the downwind samples; PCE, TCA, and TCE were detected in three of these samples (including one duplicate) at concentrations exceeding 1000 ng/OC.

These results are consistent with what was suspected in the area of the test pits, based on the fact that elevated soil gas results were noted for the northern test pit (TP2) and not for the southern (TP1; see subsection 4.2 for soil gas results). The results are also consistent with the results of subsurface soil sampling (see subsection 4.5), which show the presence of TCA, PCE, TCE, 1,2-DCE(total), and xylene at ppm-level concentrations in the area surrounding the test pits.

Test pit air samples were converted from ng/OC to parts per billions per volume (ppbv) in order to facilitate comparison with occupational health standards, including the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limits (RELs), and the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs). Sample results in ppbv are provided in Appendix I. The equations and conversion calculations are provided in Appendix H-2b. As seen in Table I-2, occupational standards for the compounds detected are in the ppm range, with the exception of benzene which has an REL of 100 ppb. There were no air samples at either test pit in which compounds were detected at a concentration above a standard value. Two compounds, methylene chloride and PCE, do not have numerical RELs; rather, NIOSH recommends trying to attain the lowest level possible. However, the PELs and TLVs for these compounds were not exceeded. None of the test pit air samples, which could be used to estimate occupational exposure during a construction/excavation scenario, exceeded occupational standards.

4.4 Results of Surface Soil Sampling

Surface soil samples were collected in order to determine if surface soil contamination was present and likely to impact human health. Surface soil sampling was conducted in Areas 4 and 7 on September 22, 1993 using the methods discussed in subsection 2.6. Samples were collected in areas that were most likely to have surface contamination based on previous subsurface sampling results. The sampling locations were also chosen because they were in or near residential areas, or areas where human contact with the soil was more likely.

As described in subsection 2.6, surface soil samples were collected by cutting a grass plug from the sampling area with a garden trowel, collecting the soil underneath at an approximate depth interval of 6 inches to 1 foot, and replacing the plug. Samples were analyzed for Target Compound List (TCL) Organics and Target Analyte List (TAL) Inorganics. The full results for surface soil samples are presented in Appendix H-3. Surface soil samples are named with an "SS" prefix followed by a location number. In Area 7, these locations are the same as the soil boring (SB) locations and the MW134C well location. Thus sample SS7-1 and SS134C were collected at the SB7-1 and MW134C locations. In Area 4, the surface soil samples are taken at different locations from the soil borings. One sample was collected about 50 feet west of the soil borings; the other sample was collected about 100 feet southwest of the borings, on the northeast corner of Alton and Marshall Streets.

Area 7

Seven surface soil samples (plus one duplicate) were collected in Area 7. Sampling in Area 7 indicated VOC contamination with methylene chloride, acetone, 1,1-DCA, 1,2-DCE(total), 1,2-DCA, TCA, TCE, PCE, toluene, and xylene.

Methylene chloride was detected in all Area 7 samples, and acetone was detected in all but two samples. The highest concentrations, 33 ppb and 62 ppb respectively, were exhibited in SS7-10. Methylene chloride and acetone are both common laboratory contaminants, so their detection in

the samples at these levels could indicate laboratory contamination rather than true sample contamination.

Sample SS7-1, collected from the northwestern corner of the basketball court, exhibited no other VOC contamination besides the methylene chloride and acetone. Samples SS7-2, SS7-3, and SS7-23 each exhibited contamination with the above-mentioned compounds, but at levels below 10 ppb (except for methylene chloride and acetone). SS7-21, approximately 75 feet south of the basketball court, exhibited notable PCE contamination (75 ppb), along with 4 ppb TCE. PCE was also detected at 21 ppb in SS134C, approximately 150 feet west of the playground, along with 14 ppb toluene, and 1,2-DCA, TCA, and xylene at values at or below 10 ppb. Sample SS7-10, collected approximately 300 feet south of the basketball courts, exhibited the most contamination. VOCs detected in this sample were 220 ppb 1,2-DCE (total), 40 ppb TCA, 140 ppb TCE, and 400 ppb PCE, as well as 1,1-DCA and toluene at or below 8 ppb. The higher VOC results from SS7-10 are consistent with the results of subsurface soil sampling at SB7-10, which showed that high contaminant concentrations are present at a shallow depth (five feet); in other borings the high-contamination interval begins at about 10 to 15 feet.

Bis(2-ethylhexyl)phthalate was detected in all samples, with the highest concentration being 570 ppb in SS7-10. Other semivolatile compounds were detected in SS7-10 and SS7-23. Isophorone and benzo(a)pyrene were detected in SS7-10 at 150 and 170 ppb respectively. Fluoranthene and pyrene were detected at 42 and 37 ppb in SS7-23, located approximately 150 feet south of the southeastern corner of the basketball court. As noted above, bis(2-ethylhexyl)phthalate is a plasticizer and is used in vacuum pumps. Though low environmental concentrations of bis(2-ethylhexyl)phthalate are commonly the result of laboratory or sampling contamination, these concentrations are likely to exist in the soils; the presence of bis(2-ethylhexyl)phthalate in surface soils may be due to the presence of plastic in the disposed wastes in Area 7. Isophorone has a wide range of uses, including as a solvent for paints, vinyl resins, tin coatings, agricultural chemicals, and cellulose esters; in storing lacquers; and in pesticide manufacturing. Benzo(a)pyrene, fluoranthene, and pyrene are polycyclic aromatic hydrocarbons (PAHs), a group of compounds which are present in small amounts in petroleum products and coal. Release of these compounds to the environment occurs largely as air emissions through the incomplete combustion of petroleum products and wood; lesser amounts are released to the land through disposal of used oils.

A number of pesticides were detected in Area 7 surface soil samples. Compounds detected in SS7-10 included dieldrin, 4,4'-DDE, and endosulfan II at concentrations at or below 15 ppb, along with 35 ppb 4,4'-DDT, 33 ppb endrin aldehyde, 20 ppb gamma chlordane, and 450 ppb of the PCB Arochlor-1260. Dieldrin was detected in SS7-2 and SS7-21 at 36 and 23 ppb. 4,4'-DDT was detected in SS7-23 at 12 ppb. Endrin aldehyde was detected in three samples below 10 ppb. 4,4'-DDT was also detected in low concentrations in SS7-2. The presence of pesticides is likely due to agricultural activities in the area.

Inorganics analysis in Area 7 indicated slight exceedances of national averages for beryllium and thallium in selected samples (Shacklette & Boerngen, 1984). High lead values (151 to 180 ppm) were detected in SS7-10, SS7-21 and SS7-23. Sample SS7-10 also exhibited values of cadmium,

copper, nickel, and silver above national averages. In addition, mercury was detected at 2.2 ppm, and cyanide was detected at 2.9 ppm. These are not naturally-occurring concentrations.

Overall, there was mild to moderate surface soil contamination displayed in Area 7 samples, particularly SS7-10, SS7-21 and SS134C. SS7-10 exhibited a broad spectrum of organics and inorganic contaminants, some at high levels. In general, surface soil contaminants comprised constituents that were also present in subsurface soils. However, volatilization of the higher vapor pressure compounds such as TCA and TCE has caused a relative reduction of these compounds in surface soils compared to subsurface soils, and a proportional increase of less volatile constituents such as PCE, semivolatiles, pesticides, and inorganics. The presence of contamination in surface soils may be a result of construction activities which moved subsurface materials to the surface or a result of surficial waste disposal of liquid wastes.

Because of the high VOC concentrations, the data from SS7-10 was evaluated with respect to possible exposure routes. The most plausible route of exposure would be a possible inhalation hazard to people playing on the courts.

To qualitatively assess this possibility, the upwind air sampling results from test pit 2 were used as an approximation of the concentrations of VOCs which may be volatilizing from the surface soil to the breathing zone of the basketball courts. Test pit 2 is located between the basketball courts and SS7-10. These air samples can be compared to occupational guidelines, but it is more appropriate to compare them to the SLAC-M values. These Screening Level Ambient Concentrations Maximums for a 24-hour period are developed by OCS to protect against adverse health effects during a 24-hour exposure as opposed to a lifetime exposure.

The air samples were well below the SLAC-M values except for acetone and 2-butanone. SLAC-M values for these two chemicals have not been developed. The test pit air sample results were mostly less than 1 ppbv (parts per billion by volume). The highest concentration was for acetone at 1.39 ppbv.

Another comparison option are the risk based concentrations (RBCs) for residential soil developed by USEPA Region III. These concentrations combine toxicity values with standard exposure scenarios to calculate acceptable chemical concentrations in various media. Simply put, RBCs are risk assessments run in reverse. The RBCs for residential soil are based on incidental ingestion of soil by children. These are appropriate comparisons for exposures that children may receive while playing in the weedy area of SS7-10. The SS7-10 VOC values are also well below the RBC values.

Based on these two factors, it does not appear that the surface soil contamination would cause adverse health effects to people utilizing the park.

Area 4

Two surface soil samples were collected in Area 4 (Figure 4-12). Sampling indicated that methylene chloride, 1,2-DCE(total), 1,2-DCA, TCA, TCE, and toluene were present. Methylene chloride, 1,2-DCA, TCA, and toluene, detected in SS4-7, were all present at 17 ppb or below.

Contamination detected in SS4-8, however, included 18 ppb methylene chloride, 110 ppb TCA and 25 ppb TCE. Toluene and 1,2-DCE(total) were present at 3 ppb.

Contamination with semivolatiles was detected in both Area 4 samples. Bis(2-ethylhexyl) phthalate was detected in both samples; however, in SS4-7 it was detected at 1400 ppb, which is generally higher than levels that commonly occur due to laboratory or sampling-derived contamination. The PAHs fluoranthene, pyrene, chrysene, and benzo(b)fluoranthene were detected in both samples between 100 and 170 ppb; benzo(k)fluoranthene was detected in both at 84 ppb. Benzo(a)pyrene was detected in SS4-7 at 140 ppb. As noted under Area 7, PAHs are commonly released to the air through combustion, or to the ground through disposal.

Low-level, but diverse pesticide contamination was detected in SS4-7. The PCB compound Aroclor-1260 was detected at 100 ppb. 4,4'-DDT and endrin aldehyde were detected at 22 and 17 ppb. These two compounds were also detected in SS4-8 at concentrations below 10 ppb. Compounds detected below 10 ppb included heptachlor epoxide, 4,4'-DDE, 4,4'-DDD, alpha-chlordane, and gamma-chlordane. These are common pesticides used at homes and commercial establishments for weed and insect control. The source of these compounds in Area 4 is unknown.

Inorganics analysis in Area 4 indicated six metals present above national averages; zinc, chromium, copper, lead, magnesium, and selenium. In sample SS4-7 the zinc and lead concentrations (554 ppm and 92 ppm) were also above the typical range of concentrations in soils (Shacklette B. Boerngen, 1984). Cyanide was also detected in this sample at 4.8 ppm. These metals could be the result of fugitive dust from local metal working facilities or local car repair shops.

4.5 Results of Subsurface Soil Sampling

Subsurface soil sampling was conducted for two purposes: 1) to collect samples in identified potential source areas in order to evaluate the likelihood of those areas acting as source areas that result in groundwater contamination; and 2) to collect samples in the contaminated unconsolidated aquifer but away from potential source areas, in order to characterize the solid material of the aquifer. For the former purpose, subsurface soil sampling was conducted in Areas 2, 4, 7, 9, 11, 12, and 14. These were seven of the 12 areas that were sampled for soil gas in Phase II and which showed elevated soil gas results for the target compounds; consequently, these areas were passed on through the potential contaminant source screening process to the next screening step, which was subsurface soil sampling. Subsurface soil sampling was conducted between June and December, 1993, using the methods described in subsection 2.6.

4.5.1 Results of Subsurface Soil Sampling in Potential Source Areas

As described in detail in subsection 2.6, subsurface soil samples were collected using split-spoon samplers; in potential source areas, the sampling interval was generally five feet. Samples were field-screened for total VOCs by the head-space method. Samples were selected for laboratory analysis based on head-space concentrations: in general, the sample with the highest head-space

concentration, and the first "clean" sample (or nearly clean) beneath the contaminated interval, were selected for analysis for TCL Organics and TAL Inorganics. Where no sample from a particular boring contained detectable VOCs in head-space screening, the sample nearest to (and generally above) the water table was selected for analysis. For soil samples with limited sample volume, samples were submitted for analysis of VOCs only. The full analytical results for subsurface soil samples are presented in Appendices H-4 through H-6.

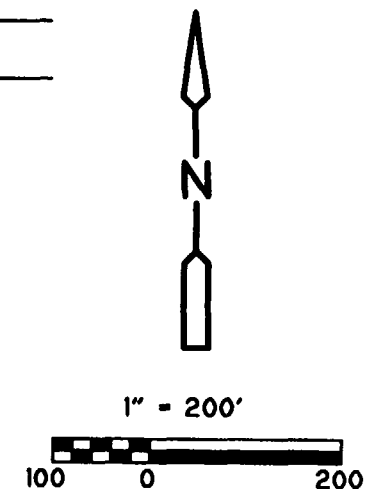
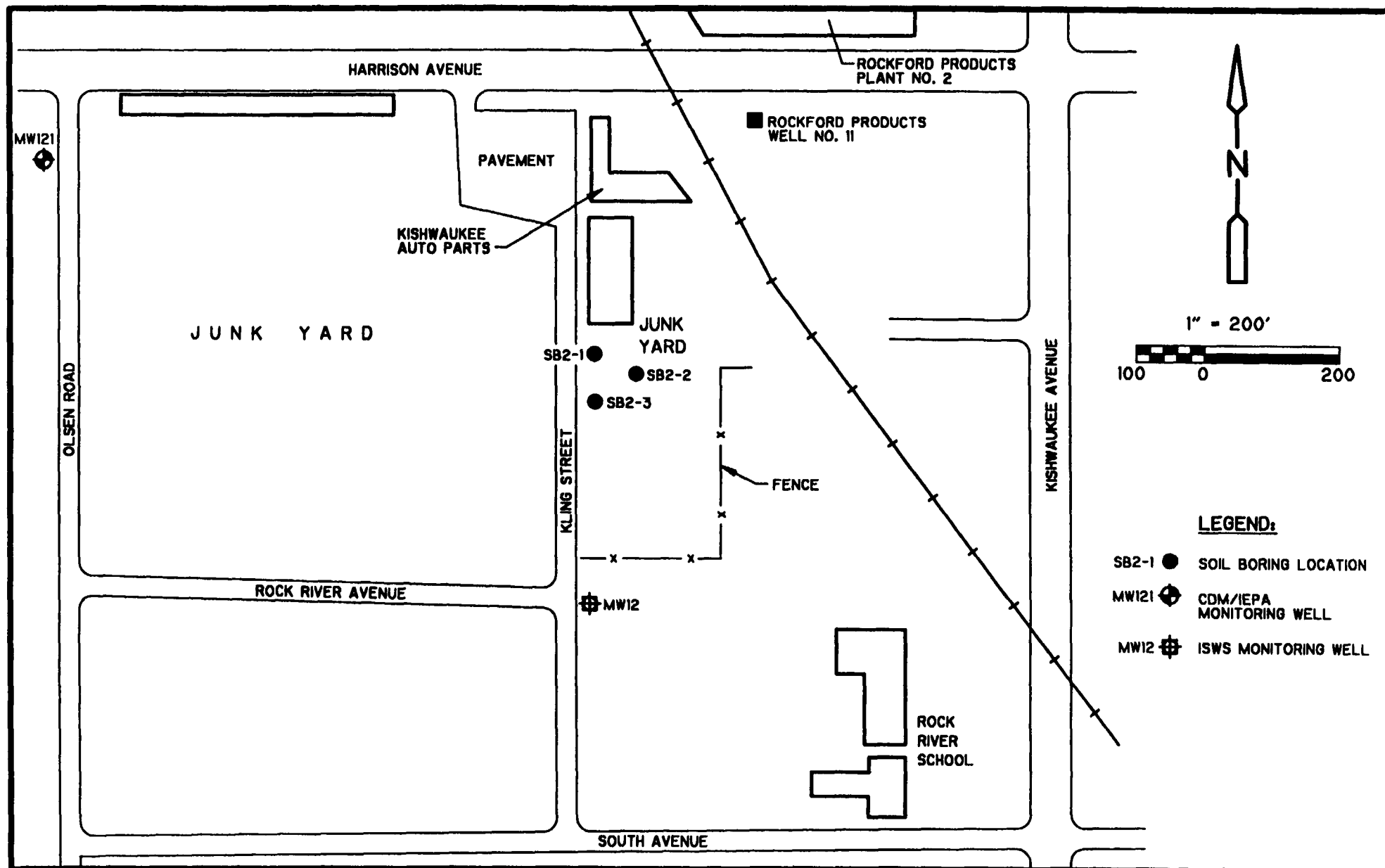
4.5.1.1 Area 2

Subsurface soil sampling was conducted in Phase II in Area 2 to investigate an area of moderate concentrations of PCE in soil gas samples collected in Phases I and II. The anomalous soil gas sampling results were clustered along Kling Street and in the junk yard east of Kling Street. Three soil borings in Phase II were placed in the west-central part of the junk yard, at locations near and between the anomalous soil gas results (see Figure 4-11). None of the subsurface soil samples displayed detectable VOCs in field head-space screening, and there was no visual evidence of contamination in any sample. Analytical samples selected from the three borings (one from each boring) displayed relatively low-level concentrations of VOCs, with acetone, 1,2-dichloroethene (1,2-DCE) (total), PCE, and toluene detected in one or two samples each. PCE was reported at the highest concentration from these samples, with 82 ppb (parts per billion; equivalent to the reported units of $\mu\text{g}/\text{kg}$) from sample SB2-3D (collected at 17-19 feet below grade). A duplicate sample was collected from this location, and this sample yielded a PCE concentration of 19 ppb. Though considerably different from the primary sample, such contrasts between primary and duplicate samples are common in soil samples, due to the inherently variable nature of soil materials. Nevertheless, the duplicate result supports the idea that PCE is present in sample SB2-3D, but at low concentrations. In the second sampling location where PCE was reported (SB2-1C), (collected at 15-17 feet below grade) its concentration was 4 ppb. The other compounds listed were detected in only one sample each, and at concentrations of 4 to 7 ppb.

The results of subsurface soil sampling in Area 2 are consistent with the soil gas survey results in that PCE was the most abundant of the target chlorinated organic compounds (TCA, TCE, and PCE). However, the subsurface sampling results were somewhat lower than what was expected based on soil gas results. The combination of moderate PCE concentrations in soil gas samples and low PCE results from subsurface soils in Area 2 suggests that a PCE contaminant source is likely present, but that such a source is diffuse, and relatively low in concentration.

Several extractables and pesticides were detected from soil samples collected in Area 2. Bis(2-ethylhexyl)phthalate was detected in two of the three samples, at concentrations of 100 and 38 ppb. Though this compound may indeed be present in these samples, it is more likely that these low concentrations reflect low-level contamination during analysis or sampling. This interpretation is favored by the fact that bis(2-ethylhexyl)phthalate was detected in many other subsurface soil samples at similar concentrations, including samples which contained no other detectable contaminants.

The pesticides alpha-BHC and delta-BHC were each reported from one sample in Area 2, both at concentrations of 0.13 ppb. These compounds were reported from samples in other areas that

**LEGEND:**

- SB2-1 ● SOIL BORING LOCATION
- MW121 ◈ CDM/IEPA MONITORING WELL
- MW12 ◈ ISWS MONITORING WELL

SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY

SUBSURFACE SOIL BORINGS
POTENTIAL SOURCE AREA 2 VICINITY

CDM

environmental engineers, scientists,
 planners, & management consultants

Figure No. 4-11

contained VOC contaminants (several samples in Areas 4 and 11, and one sample from Area 7). While these compounds appear to be present at very low concentrations in subsurface soils in Area 2 and in certain other areas, they are not compounds of concern for groundwater; their solubilities are in the low-ppm range, and there were no reported detections of alpha-BHC or delta-BHC in groundwater samples.

Numerous inorganic constituents were detected in subsurface soil samples from Area 2. However, all these detections were of a magnitude typical of "normal" soils, based on an extensive soil sampling program throughout the United States (Shacklette and Boerngen, 1984).

4.5.1.2 Area 4

Subsurface soil sampling was conducted in Phase II in Area 4 to investigate the origin of very high soil gas concentrations of TCA (five Phase II soil gas samples and one Phase I sample ranged from 1,500 to 4,300 µg/L TCA) centered on the northern part of the Swebco Manufacturing Inc. parking lot in Area 4. In order to evaluate these concentrations, six borings were drilled in Area 4 in the central and northern portions of this parking lot (see Figure 4-12). Three of the six borings in Area 4 showed the presence of a dark, oily product at the top of the saturated zone. Field organic vapor concentrations measured with an HNu or OVA were consistent with visual observations, and indicate that the oily product was not discernible at shallow depths but was present in the first saturated sample, at an approximate depth of 28 feet (see Table 4-2). At borings SB4-1 through SB4-5, borings were terminated within 10 feet of the water table, due to the inability to obtain completely reliable, undisturbed subsurface soil samples while using the hollow-stem auger drilling method. Boring SB4-6, however, was drilled using the mud rotary method, which allowed more effective sampling below the water table. At this boring, drilling and sampling proceeded to a depth of about 42 feet, approximately 14 feet below the water table; at this depth organic vapor concentrations had begun to decline markedly. Based on field organic vapor scanning along the length of the deepest sample at SB4-6, only the interval above 40.5 feet had organic vapor concentrations above 1.0 ppm. The interval of observed free-product contamination appears to end at a somewhat shallower depth: within the 35 to 37-foot sample, the color of the sample ranges from black (above 35.4 feet) to gray (from 35.4 to 35.8 feet) to light yellow brown (below 35.8 feet), which is the typical color of the subsurface sandy soils; organic vapor concentrations in this interval decreased from 20 to 60 ppm in the two upper zones, to 5 to 20 ppm in the lower, light yellow brown zone. Based on these observations, the zone of highest contaminant concentrations at SB4-6 ranged from about 28 to 36 feet, for an approximate thickness of eight feet. As the highest soil gas contaminant concentrations were centered north of SB4-6, it is likely that the maximum thickness of highly contaminated soil in Area 4 is somewhat greater than eight feet.

As summarized in Table 4-2, TCA was the predominant contaminant in subsurface soils analyzed from Area 4, being present at up to 360 ppm (360,000 µg/kg or ppb) in sample SB4-1F. This pattern is consistent with the results of the Phase I and Phase II soil gas survey locations on or adjacent to the Swebco Manufacturing Inc. facility, where TCE and PCE were present at concentrations less than 6% and 1%, respectively, of that of TCA. As discussed in subsections 4.8 and 4.10, groundwater sampling results are also consistent with this pattern, as samples downgradient of Area 4 are abnormally high in TCA, and proportionally low in TCE and PCE.

M. KUZEL, NMW-CHI

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FIG4-12

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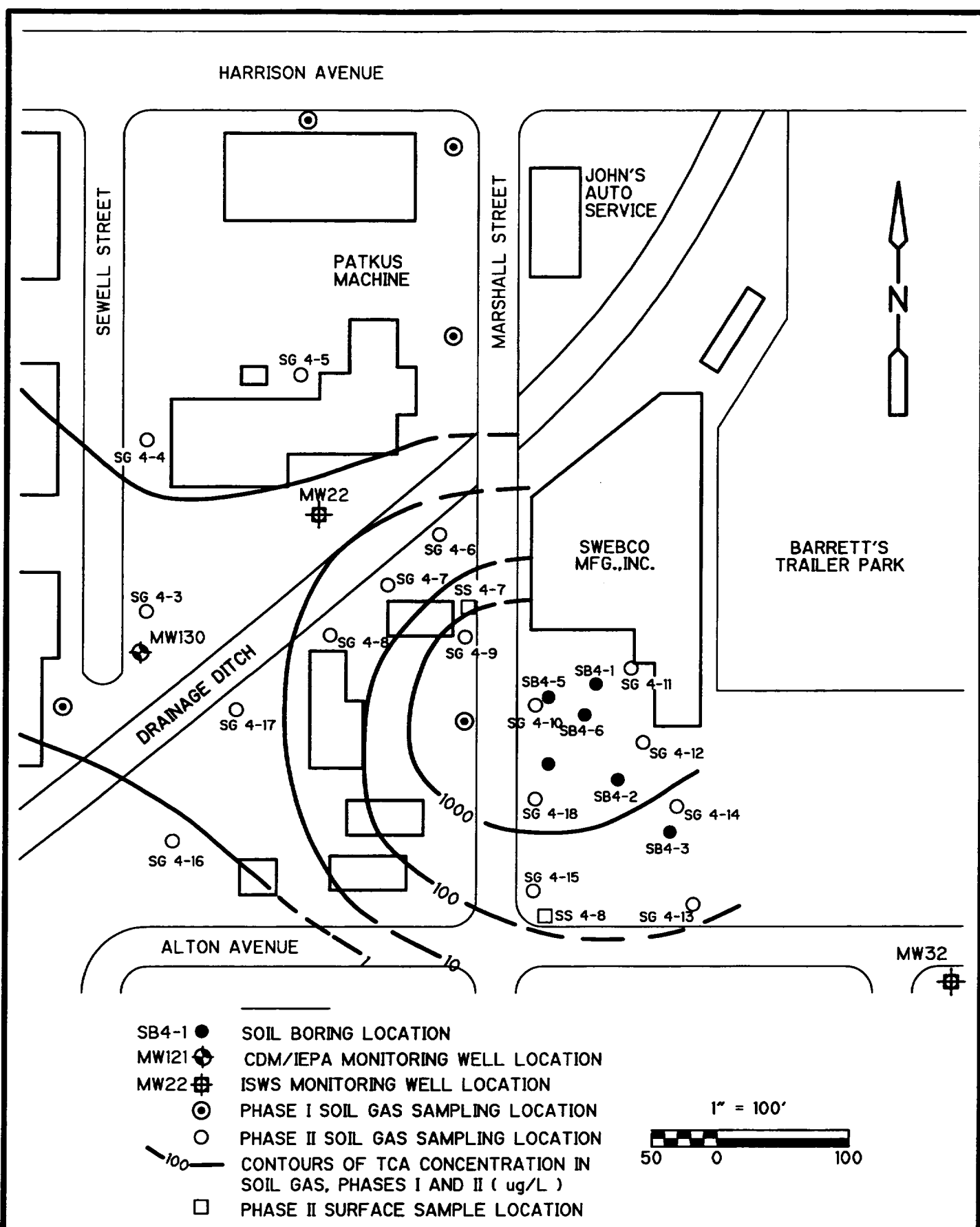


TABLE 4-2
Summary of Subsurface Soil Sampling Results,
Area 4

Sample Number	Depth, feet ¹	Field Screening with HNu, ppm: scan/head space	Analytical Results	
			Total VOCs, ppb	TCA, ppb
SB4-1A	5-7	0/0	--	--
SB4-1B	10-12	0/0	--	--
SB4-1C	15-17	0/0	--	--
SB4-1D	20-22	0/0	N.D.	N.D.
SB4-1E	25-27	1.8/0.5	--	--
SB4-1F	30-32 *	90/50	360,000	360,000
SB4-1G	35-37 *	75/34	--	--
SB4-2A	5-7	3/0	N.D.	N.D.
SB4-2B	10-12	0/0	--	--
SB4-2C	15-17	0/0	--	--
SB4-2D	20-22	0.2/0	10	5
SB4-2E	25-27	0/0	--	--
SB4-2F	30-32 *	0/0	--	--
SB4-2G	35-37 *	--	--	--
SB4-3A	5-7	0/0	--	--
SB4-3B	10-12	0/0	--	--
SB4-3C	15-17	0/0	--	--
SB4-3D	20-22	0/0	--	--
SB4-3E	25-27	0/0	53; 34 ²	N.D.; N.D.
SB4-3F	30-32 *	0/0	--	--
SB4-4A	5-7	0/0	--	--
SB4-4B	10-12	0/0	--	--
SB4-4C	15-17	0/0	--	--
SB4-4D	20-22	0/0	--	--
SB4-4E	25-27	0/0	13	9
SB4-4F	30-32 *	0/0	--	--
SB4-5A	5-7	0/0	--	--
SB4-5B	10-12	0/0	--	--
SB4-5C	15-17	0/0	--	--
SB4-5D	20-22	0/0	--	--
SB4-5E	25-27	0/0.5	27	6
SB4-5F	30-32 *	44/34	190,000	190,000
SB4-5G	35-37 *	70/53	--	--
SB4-6A	25-27 *	0/0.5 ³	--	--
SB4-6B	30-32 *	95.5/91.4 ³	--	--
SB4-6C	35-37 *	60.5/42.2 ³	--	--
SB4-6D	40-42 *	4.2/0.5 ³	--	--

¹ - Asterisk indicates sample is saturated

² - Second value refers to result for duplicate sample

³ - Readings measured with OVA

The other VOCs that were detected in Area 4 borings were toluene, acetone, chlorobenzene, PCE, and benzene. The most abundant of these was toluene, detected in four samples at concentrations up to 41 ppb; acetone was the second-most abundant, and was detected in four samples at concentrations up to 9 ppb. These detections were in the low-concentration samples from Area 4; higher concentrations of these and perhaps other compounds are likely to have been present in the oily samples SB4-1F and SB4-5F. The detection limits for these two samples were 28 and 14 ppm, respectively, which is approximately 8% of the concentration determined for TCA. Nevertheless, it is clear that TCE and PCE are much less abundant than TCA in the subsurface soils in Area 4.

The extractable compounds naphthalene (up to 3,000 ppb), 2-methylnaphthalene (1,600 ppb), phenanthrene (580 ppb), and bis(2-ethylhexyl)phthalate (260 ppb) were detected in Area 4 subsurface soils. The first three compounds listed are polycyclic aromatic hydrocarbons (PAHs) which were detected only in samples SB4-1F and SB4-5F; this pattern is to be expected, as these compounds are common constituents of waste oils. Bis(2-ethylhexyl)phthalate was detected in four of the nine Area 4 subsurface soil samples; in contrast to the samples with PAH detections, all of these samples had very low to undetectable concentrations of other compounds. The low magnitude and the lack of association of bis(2-ethylhexyl)phthalate with other compounds suggests that it was detected as a result of low-level contamination during analysis or sampling.

A number of tentatively identified compounds (TICs) were reported from both the volatile and semivolatile scans of the two oily subsurface samples from Area 4 (SB4-1F and SB4-5F). In the volatile scan most of these compounds were not identified, and the total of the TICs was about 25 and 60% of the TCA concentration in samples SB4-1F and SB4-5F, respectively. In the semivolatile scan more of the compounds were identified and were alkanes such as decane and tetradecane; along with the unidentified alkanes, the total concentration of alkanes in the semivolatile scan was about 290 and 170% of the TCA concentration in SB4-1F and SB4-5F, respectively. Very high concentrations of an "unresolved hydrocarbon complex" were reported for both SB4-1F and SB4-5F, at concentrations of about 20 and 50 times that of TCA, respectively. Though the identities and quantities of reported TICs are not entirely reliable, these results show that the high-concentration subsurface contamination in Area 4 probably consists of a mixture of TCA and hydrocarbons, some of which are alkanes which are characteristic of oils. Such a mixture would likely have a density similar to, or probably less than, that of water; this would explain the fact that it was observed only at the top of the saturated zone.

The following pesticide compounds were detected in one or more subsurface soil samples from Area 4, followed by the maximum detected concentration: alpha-BHC (4 ppb), beta-BHC (5.9 ppb), delta-BHC (1.8 ppb), gamma-BHC (1.6 ppb), heptachlor (5.2 ppb), aldrin (2.3 ppb), endosulfan I (5.7 ppb), 4,4'-DDE (0.34 ppb), endosulfan II (0.44 ppb), 4,4'-DDD (0.24 ppb), 4,4'-DDT (0.59 ppb), methoxychlor (3.7 ppb), and endrin aldehyde (1.5 ppb). Pesticides were detected at seven of the nine samples, but the highest concentrations were limited to the two oily samples (SB4-1F and SB4-5F). Many of these compounds were detected in subsurface samples from other source areas (areas 7, 11, and 12), but the highest concentrations of these compounds were from the surface soils (see subsection 4.4). The pesticides are not compounds of concern for the study area, because none were detected in groundwater samples. The presence of pesticides are most likely attributed to residential/commercial weed and insect control.

No inorganic compounds were detected in Area 4 at concentrations greater than local background concentrations for subsurface soils in the study area.

Comparison of subsurface soil sampling results with soil gas results shows the influence of local conditions on the soil gas results. For example, soil gas survey locations SG4-12 and SG4-18 had very high TCA concentrations (3,200 and 2,400 µg/L, respectively). However, soil borings SB4-2 and SB4-4 were placed near these locations (see Figure 4-12), and showed only low ppb levels of contamination. The area of anomalous soil gas sample results (greater than 100 µg/L of TCA) constitutes an area of approximately 150 by 200 feet. However, Phase II subsurface soil sampling showed that the area underlain by TCA-contaminated soil is somewhat smaller, being only about 50 by 75 feet, and limited to the northern part of the parking lot. It is instructive to note that all of the Area 4 soil gas samples with concentrations greater than 100 µg/L TCA were collected from beneath or within several feet of a continuously paved area (the Swebco Mfg. parking lot or Marshall Street). The larger area of anomalous soil gas readings (compared to the area underlain by TCA-contaminated soil) is likely a result of the pavement acting as an impermeable barrier to the escape of TCA to the atmosphere. Rather than escaping from the soil by passing upward through unpaved ground, contaminants volatilizing off the subsurface source area beneath the northern part of the parking lot appear to migrate beneath the pavement toward unpaved areas, where volatilization to the atmosphere can occur. This would account for the high soil gas concentrations found at locations SG4-12, 14, and 18, while soil borings show that the area of TCA-contaminated soil does not exist this far south (based on soil borings SB4-2, 3, and 4). Beyond a few feet past paved areas, TCA soil gas concentrations decline to much lower concentrations of less than 50 µg/L.

The area and volume of contaminated soil in Area 4 can be estimated from the results of the RI. The borings containing residual free product in the soil samples cover an area of 23.5 by 36 feet. As the contaminated zone appeared to be at least five feet thick at all three locations, it could be assumed that the contamination extends some distance in all directions from this rectangular area. While subsurface borings do not give direct evidence on the northerly extent of contamination, the northern boundary can be inferred from other evidence. Soil gas sample SG4-6 had a TCA concentration of 36 µg/L, much lower than the concentration in sample SG4-9 (1,500 µg/L) located about 80 feet to the south (see Figure 4-12). In addition, ISWS monitoring well MW22 is located downgradient (west-northwest) of the Swebco Mfg. building, but shows background TCA concentrations (20 ppb); MW130, on the other hand, is located roughly downgradient of the contamination beneath the northern part of the parking lot, and shows highly elevated TCA concentrations of 1,000 ppb (see Figure 4-12). Considering this evidence, it appears that the area of high contamination does not extend far north of the southern boundary of the building. The eastern and western extent of contamination are also not known with certainty. However, the western boundary likely does not extend far west of Marshall Street, if at all, because soil gas concentrations rapidly decline to the west. In fact, the elevated concentrations immediately west of the street (SG4-9 and the Phase I location with 3,400 µg/L) may be a function of their location adjacent to a paved area, similar to SG4-12 and SG4-18 discussed above. Based on these lines of evidence, a reasonable preliminary estimate for the area of highly contaminated soil in Area 4 is 50 by 75 feet, with the long dimension being east-west. Using an assumed thickness of eight feet, an average TCA concentration of 275 ppm (see Table

4-2), and an assumed bulk density of 1.9 g/cm³, the volume of highly contaminated soil is approximately 1,100 cubic yards, and the weight of TCA is approximately 977 pounds.

As shown in Table 4-2, field organic vapor screening results correlate well with laboratory sampling results. Screening results near 1 ppm or less correspond with analytical results of low concentrations (50 ppb or less), and elevated screening concentrations correspond with ppm-level concentrations. The single exception to this correlation was in the scan result (not the head-space result) for sample SB4-2A: in this sample the 3 ppm scan came from a single narrow zone of the sample; upon sampling, this zone was composited with the remainder of the sample, which was uncontaminated, diluting the effect of the narrow zone. For the purpose of comparing to an analytical result, the head-space results are more reliable than the sample scanning results, because they, like the analytical samples, are based on composite sampling. The scanning results are useful for evaluating vertical variations in VOC concentrations within a sample.

Based on historical information and existing analytical and stratigraphic data, nonaqueous phase liquid (NAPL) contamination is suspected in Area 4. The Phase II study was designed to evaluate the potential for NAPLs in the subsurface, not to investigate and characterize NAPL zones. The information obtained from soil gas, soil samples, headspace screening and visual observations indicates that there may be residual NAPL present in the vadose zone near the water table, particularly within the 1000 ppb soil gas contour as shown on Figure 4-12. It is suspected, based on the physical properties of the primary contaminants (TCE, TCE, and PCE) and anecdotal disposal reports, that there may also be DNAPL (dense nonaqueous phase liquid) zones at depth within the saturated zone. No specific testing was performed to confirm or characterize the suspected NAPL near the water table. Additionally, no borings or wells were completed deeper than 42 feet bgs within the source area so no deeper NAPLs were encountered during Phase II.

Based on guidance from USEPA, DNAPL Site Characterization (USEPA, September, 1994), NAPL investigations should be performed in phases. The initial phase would include developing a conceptual model and subsequent phases would include specialized investigation activities to help refine the conceptual model. These activities would be followed by risk assessment, evaluation of remedial alternatives, treatability studies and ultimately, remediation. Future source area studies should be designed using the existing information from Phase II to develop an initial conceptual NAPL model. Subsequent NAPL investigations (if deemed necessary), should make a distinction between mobile versus residual NAPL and should be designed to minimize the risks of spreading NAPL.

4.5.1.3 Area 7

Chlorinated VOCs

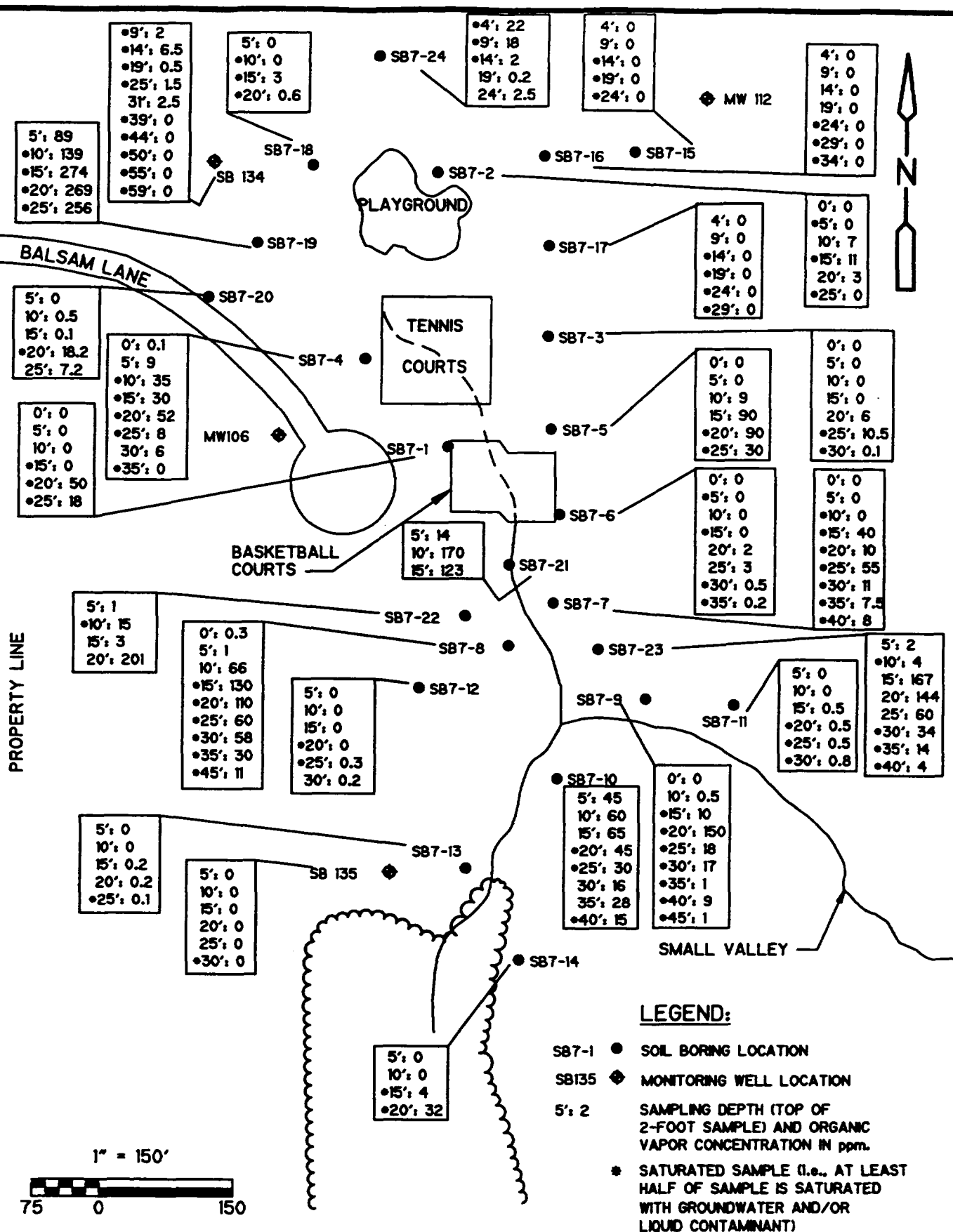
Subsurface soil sampling was conducted in Area 7 in order to investigate and characterize the source of moderate to very high soil gas concentrations of TCA, PCE, and TCE (see subsection 4.2), as well as to follow up on the test pit results (see subsection 4.3), geophysical anomalies, and observations of debris in the soil. The soil gas concentrations range up to 3,800 µg/L for

TCA, 1,100 µg/L for PCE, and 690 µg/L for TCE, and cover an extensive area of about 300 by 1,100 feet. Twenty-four borings were drilled and sampled in Area 7 to evaluate the nature and extent of subsurface contamination; several other subsurface samples were collected from borings drilled for monitoring well installation at MW112, MW134, and MW135, which are referred to in this section as SB112, SB134, and SB135, respectively.

Most of the soil borings drilled in Area 7 showed evidence of elevated contaminant concentrations, based on field organic vapor screening (using HNu or OVA), visual and olfactory observation (color was commonly a brownish gray or gray, in contrast to the brown color of less-contaminated sands; see the boring logs in Appendix A), and laboratory analytical results. As in Area 4, field organic vapor screening provides the most complete source of information on VOC contaminant distribution; field screening was performed on each split-spoon sample collected. This information is shown in Figures 4-13 and 4-14. Comparison of these figures with Figures 4-4 through 4-7 shows that the area of anomalous VOC concentrations in subsurface soils (based on field screening) matches fairly well the area of anomalous soil gas concentrations of TCA, PCE, and TCE; in addition, the area of anomalous VOCs based on field screening also matches the laboratory analytical results from subsurface soils (discussed below and portrayed in Figures 4-15 through 4-20). The primary difference between the borings and the soil gas survey is that the soil borings were drilled over a slightly larger area. Soil borings were drilled to the north and northwest of the area covered by the soil gas survey, because the soil gas survey did not completely define the northern and northwestern boundaries of the elevated VOC soil gas readings. Several of these additional borings (SB7-19, SB7-20, SB7-24, and SB134) indeed showed evidence of elevated VOC concentrations, thereby further expanding the area underlain by source contamination.

TCA, PCE, and xylene were the most abundant VOC contaminants detected in the subsurface soils in Area 7. These compounds were generally present at the same magnitude: in samples containing more than 100 ppb of any one constituent, they were generally present at concentrations within a factor of three. TCA attained the highest concentrations of all VOCs, ranging up to 360,000 ppb (360 ppm) at SB7-24A (depth 4-6 feet) and 380 ppm at SB7-8D (depth 15-17 feet). Figure 4-15 shows the distribution of TCA in subsurface soils in Area 7. TCA was a major contaminant in nearly all subsurface soil samples, with the exception of SB7-14D. At this location, PCE and xylene were present at much higher concentrations than TCA. The contours on Figure 4-15 are based on the highest analytical result for a particular boring (two samples were submitted for analysis from most borings). These contours show that there are two separate "hot spot" areas underlain by soils containing peak levels greater than 100 ppm of TCA. The larger of these is centered between SB7-8 and SB7-10 and has dimensions of about 75 by 200 feet; the second of these is located at SB7-24, but the dimensions of this area are unknown because additional borings to close off the area were not possible. A much larger area is underlain by soils with TCA concentrations greater than 100 ppb; this area is about 300 by 1,200 feet, and generally matches the area already considered suspect, based on soil gas survey results.

After TCA, PCE is the second-most abundant of the VOC contaminants in subsurface soils in Area 7, ranging up to 260 ppm at SB7-8D. As displayed in the contour map of Figure 4-16, the distribution of PCE is very similar to that of TCA, with elevated concentrations in a roughly north-south band centered on the basketball courts. In nearly all samples analyzed, the PCE

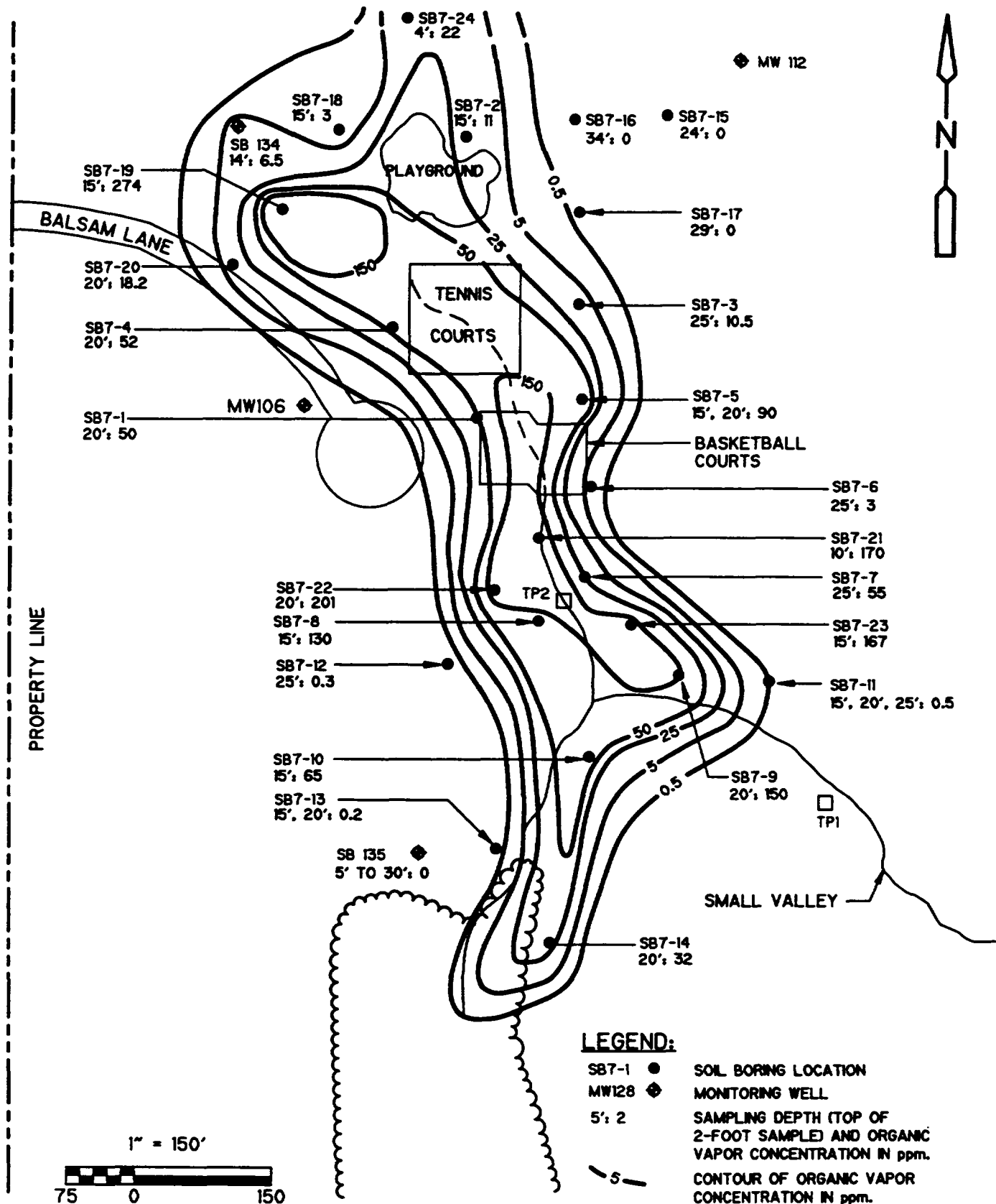


SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY
 ORGANIC VAPORS IN SUBSURFACE SOILS
 FIELD HEAD-SPACE CONCENTRATIONS, ppm
 POTENTIAL SOURCE AREA 7

05/29/94 J.S. ALFONSO

FIG 4-14

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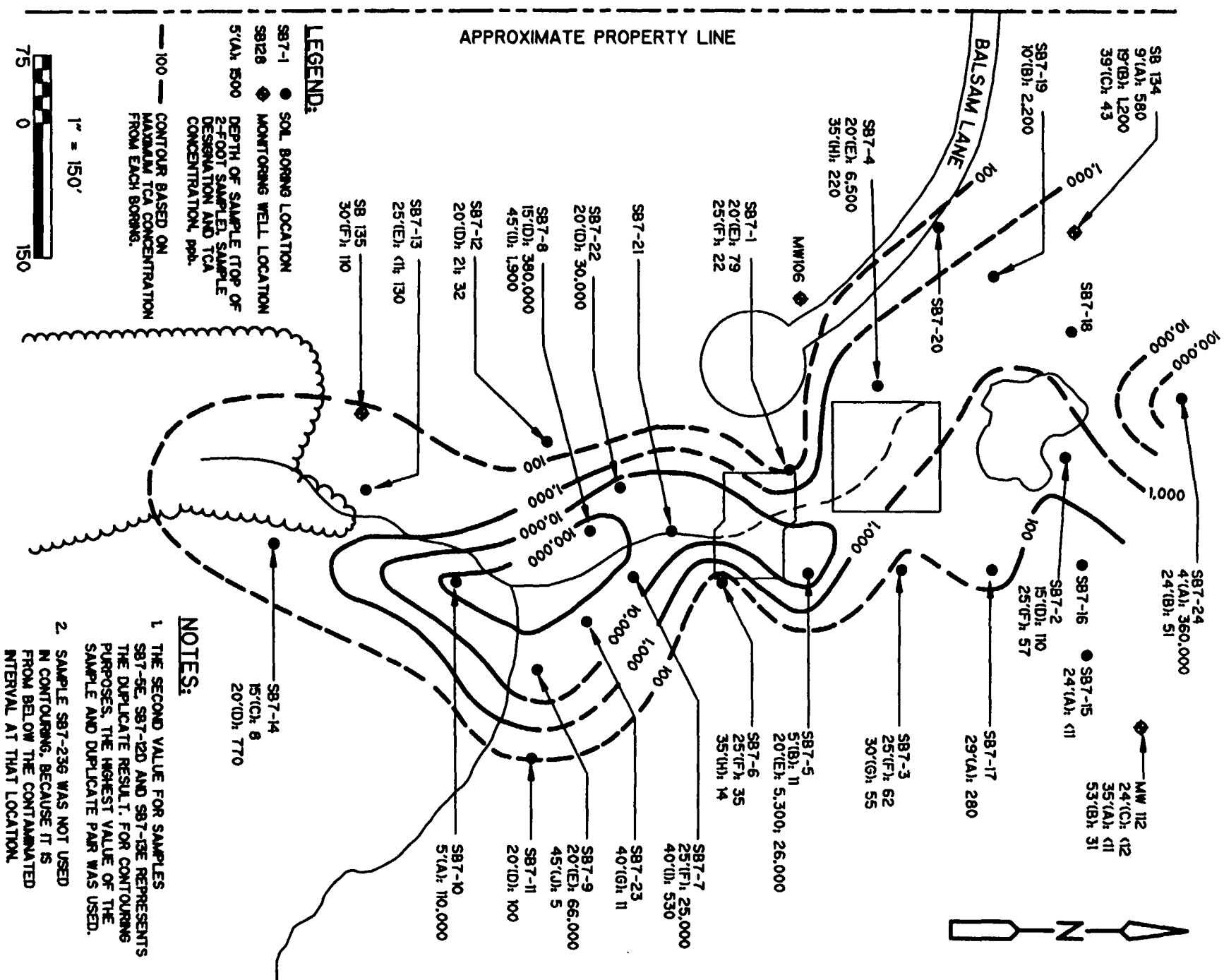


SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY
ORGANIC VAPORS IN SUBSURFACE SOILS
MAXIMUM FIELD HEAD-SPACE CONCENTRATIONS, ppm
POTENTIAL SOURCE AREA 7

CDM

environmental engineers, scientists,
planners, & management consultants

Figure No. 4-14



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**SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY
TCA IN SUBSURFACE SOILS
POTENTIAL SOURCE AREA 7**

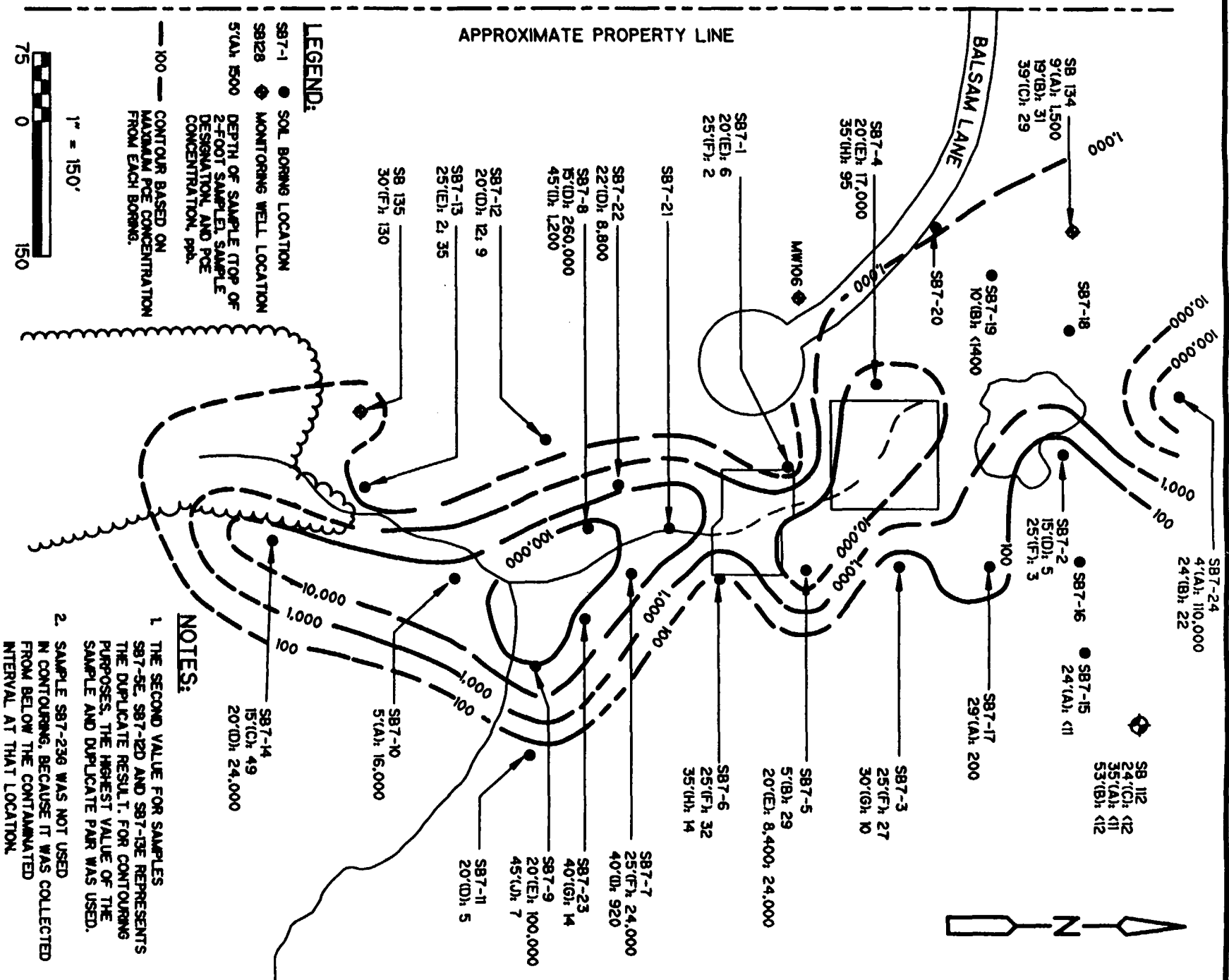
Figure No. 4-15

environmental engineers, scientists,
planners, & management consultants

CDM

SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY PCE CONCENTRATION IN SUBSURFACE SOILS POTENTIAL SOURCE AREA 7

Figure No. 4-16



concentration is on the same order of magnitude as that of TCA, generally within a factor of three. The primary exception to this pattern is at SB7-14D, where PCE was reported at a concentration about 30 times that of TCA.

The situation in Area 7 is believed to be similar to that in Area 4. Residual NAPL contamination is suspected in the vadose zone near the water table especially in the "hot spot" areas, however, no specific testing was conducted during Phase II to confirm this hypothesis. As the solid material in sample SB7-8D consists of sand and gravel with no appreciable organic matter or clays, it can be assumed that very little of the total mass of PCE in this sample was adsorbed to the solid phase. Assuming a porosity of 30% and assuming that the major fraction of PCE is in the liquid portion of the sample, the concentration of PCE in the liquid as SB7-8D is $(1/0.30) \times 260 \text{ ppm} = 867 \text{ ppm}$. This concentration is considerably higher than the solubility of PCE in water, which is 200 ppm; this contrast suggests that a NAPL is present. One component of the NAPL is comprised of a dense non-aqueous phase liquid (DNAPL) compound, PCE. Based on the PCE concentrations observed in soil in Area 7, the likely extent of a possible NAPL containing PCE as a DNAPL component would be limited to the areas encompassed by the 100,000 ppb contours in the central and norther portions of Area 7. Similar calculations for xylene, naphthalene, and 2-methylnaphthalene yield results consistent with the presence of a NAPL, comprised of light non-aqueous phase liquid compounds is present at SB7-8D, SB7-9E, and SB7-10A. Because the presence of residual NAPL has not been confirmed, subsequent discussions will refer to these areas as areas with high VOC concentrations or hot spots.

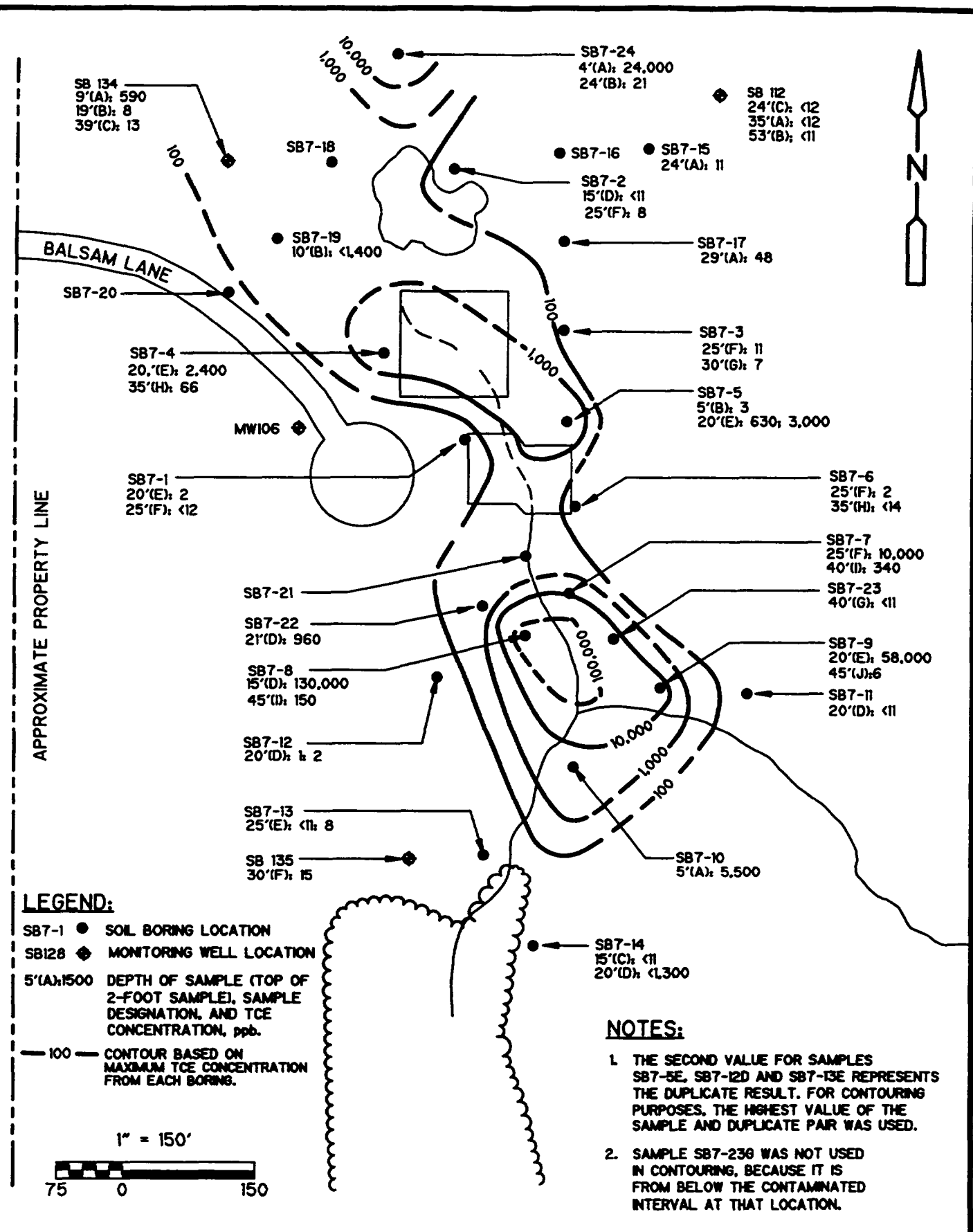
TCE is the third-most abundant of the chlorinated VOC contaminants in subsurface soils in Area 7, ranging up to 130 ppm at SB7-8D. The distribution of TCE in these soils is presented in Figure 4-17, which shows a broad area underlain by detectable concentrations of TCE. This distribution is very similar to that of both TCA and PCE, with the exception that TCE, more than the others, is particularly concentrated in the central hot spot zone encompassed by SB7-7, SB7-8, and SB7-9.

1,2-DCE (total) was fourth-most abundant of chlorinated VOCs in subsurface soils in Area 7, ranging up to 49 ppm in SB7-10A (see Figure 4-18). However, this compound had a somewhat more widespread distribution than other chlorinated organic compounds. While other chlorinated compounds had their highest concentrations at SB7-7, SB7-8, and SB7-9, the highest concentration of 1,2-DCE (total) was at SB7-10A. 1,2-DCE (total) was the most abundant compound detected in several borings located away from the highly contaminated (hot spot) zone, such as SB7-1, SB7-2, SB7-11, and SB135. The somewhat wider distribution of 1,2-DCE (total) may signify greater mobility of 1,2-DCE (total) than for TCA, PCE, or TCE. This would be a function of the relatively high solubility of the isomers of 1,2-DCE relative to TCA, PCE, and TCE: the solubility of the cis isomer is 3,500 mg/L, and that of the trans isomer is 6,300 mg/L. Higher solubilities would enable 1,2-DCE (total) to be dissolved by precipitation infiltrating through zones of high VOC concentration and subsequently transported to other areas where some deposition of the compound would occur. This explanation accounts for the fact that the areas of highest VOC contaminant concentrations comprises mainly contaminants that are relatively less soluble and less mobile, such as TCA, PCE, TCE, xylene, and toluene. This is also consistent with the fact that 1,2-DCE (total) is a major component of the groundwater contaminant plume downgradient from Area 7 (see subsection 4.8).

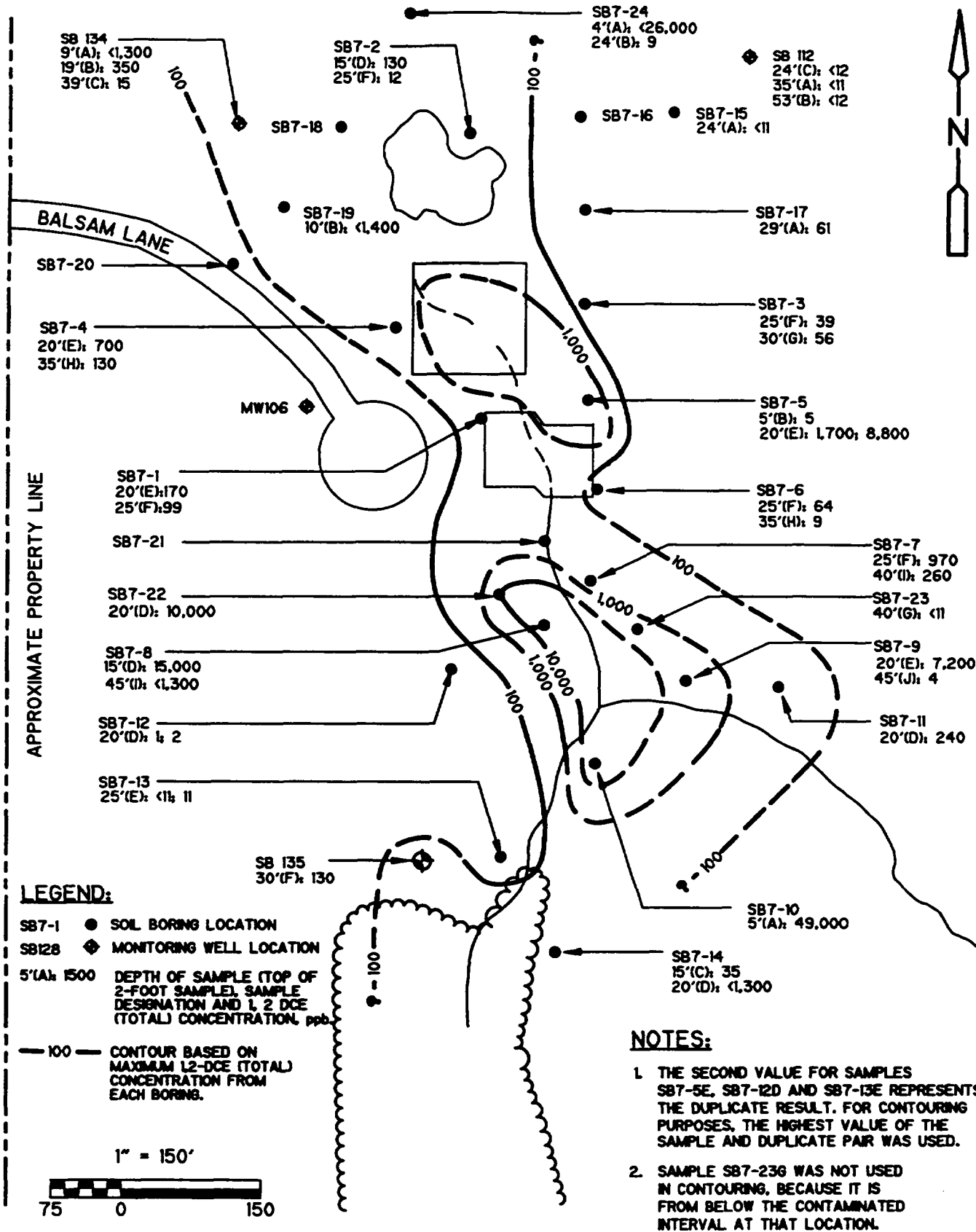
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FIG 4-17

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SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY TCE CONCENTRATION IN SUBSURFACE SOILS POTENTIAL SOURCE AREA 7



**SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY
1,2-DCE (TOTAL) CONCENTRATION IN SUBSURFACE SOILS
POTENTIAL SOURCE AREA 7**

Another feature of the distribution of 1,2-DCE (total) in subsurface soils is that it appears to be negatively correlated with TCE. Three of the four highest concentrations of 1,2-DCE (total) were from SB7-5E, SB7-10A, and SB7-22D. These are samples in which the proportion of TCE to other major contaminants is low: for example, the ratio of TCE to TCA in these samples ranges from 0.03 to 0.12, while TCE is proportionally more abundant in the other samples with high VOC concentration. This may be related to the fact that 1,2-DCE has been shown to be a common biological degradation product of TCE (Olsen and Davis, 1990). This degradation proceeds most readily in anaerobic environments; the high VOC contamination zones in Area 7 are most likely anaerobic or at least low-oxygen environments, based on the consumption of oxygen during the degradation of xylene and other readily-degraded compounds. The association of high-1,2-DCE samples with proportionally low TCE may be an indication that this degradation process occurs in the subsurface of Area 7.

After 1,2-DCE (total), the frequency and abundance of chlorinated VOC contaminants in Area 7 soils falls off considerably (see Table 4-3). The compound 1,1-dichloroethane (1,1-DCA) was the most frequently reported of these compounds, being noted in 15 of the 36 subsurface soils in Area 7. The highest concentration was 190 µg/kg (or parts per billion, ppb) at SB7-24B. Similar to 1,2-DCE (total), the highest detections of this compound were in samples away from the hot spot zones, at SB7-1 through SB7-4, SB7-24 (where the detection was noted from below the high-concentration zone), SB134, and SB135. As 1,1-DCA is also relatively soluble (5,500 mg/L), this pattern could be a function of greater mobility of this compound than for TCA, PCE, and TCE. Again similar to 1,2-DCE (total), 1,1-DCA is a relatively abundant component of the groundwater contaminant plume downgradient from Area 7.

As shown in Table 4-3, other chlorinated organic compounds were detected in up to six subsurface soil samples in Area 7; these compounds include methylene chloride, 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethane (1,2-DCA), 1,1,2-trichloroethane, and chloroform. The concentrations detected ranged from 2 to 29 ppb, with most being below 20 ppb. Of these compounds, only 1,1-DCE is an abundant component of the groundwater contaminant plume downgradient from Area 7. Its relatively greater abundance in the plume than in the Area 7 subsurface soils is discussed in subsection 4.8.

The overall pattern of the distribution of total chlorinated VOCs in subsurface soils in Area 7 is displayed in Figure 4-19. Comparison of this figure with Figures 4-15 through 4-18 shows that the chlorinated VOCs are similarly distributed across Area 7; where one of the major chlorinated contaminants in subsurface soil (TCA, PCE, TCE, or 1,2-DCE) is present, the others are also present.

Non-chlorinated VOCs

Of the non-chlorinated volatile organic compounds in subsurface soils in Area 7, xylene was the most abundant, attaining concentrations of up to 210 ppm at SB7-10A. Xylene was the third-most abundant VOC contaminant overall, after TCA and PCE. Its general distribution is similar to that of TCA, PCE, and TCE: there are anomalous concentrations in a roughly north-south strip centered on the basketball courts, and two "hot spot" zones where concentrations are especially high (100 ppm, in the area of SB7-8, 7-9, and 7-10; and at SB7-24). Similar to the case for PCE,

Table 4-3
Summary of Subsurface Soil Sampling Results in Area 7

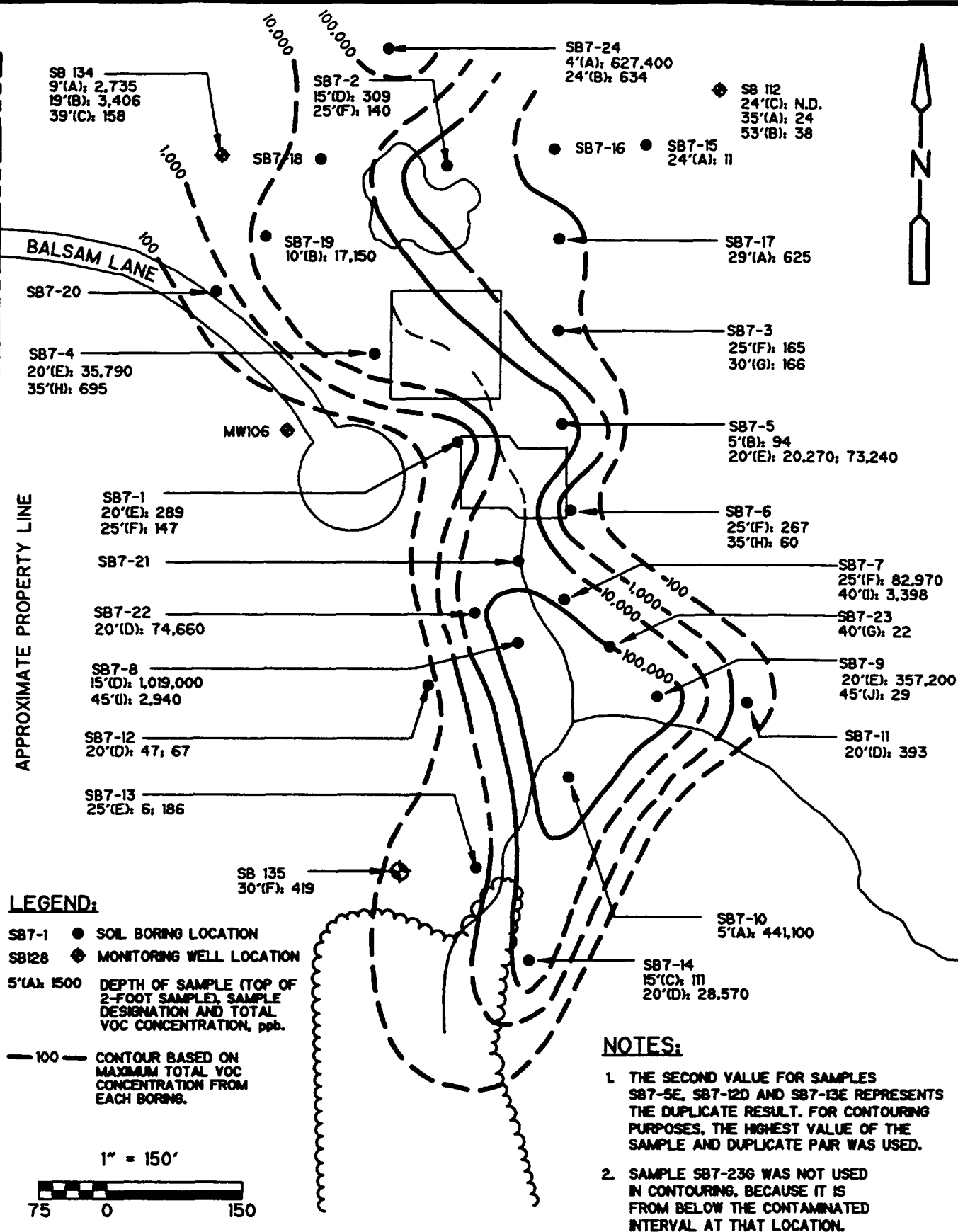
COMPOUND	Range of Area 7 Samples With Detections	Proportion of Area 7 Samples With Detections	Sample(s) With Highest Detection
Methylene Chloride	6-13	6/41(14.6%)	SB134B
Acetone	7-8400	21/41(51.2%)	SB7-24A
Carbon Disulfide	2	4/41(9.8%)	SB135F, SB134A, SB134B, SB134C
1,1-Dichloroethene	3-11	5/41(12.2%)	SB134B
1,1-Dichloroethane	2-240	16/41(39.0%)	SB7-5E(D)
1,2-Dichloroethene(total)	1-49,000	30/41(73.2%)	SB7-10A
Chloroform	2	1/41(2.4%)	SB134C
1,2-Dichloroethane	2-180	4/41(9.8%)	SB7-24B
2-Butanone	3-1500	4/41(9.8%)	SB7-14D
1,1,1-Trichloroethane	5-380,000	36/41(87.8%)	SB7-8D
Trichloroethene	2-130,000	29/41(70.7%)	SB7-8D
1,1,2-Trichloroethane	4-7	2/41(4.9%)	SB134B
4-Methyl-2-Pentanone	3-82	3/41(7.3%)	SB7-24B
Tetrachloroethene	2-260,000	36/41(87.8%)	SB7-8D
Toluene	1-23,000	30/41(73.1%)	SB7-8D
Ethylbenzene	1-31,000	19/41(46.3%)	SB7-8D
Styrene	1600	1/41(2.4%)	SB7-10A
Xylene	2-210,000	24/41(58.5%)	SB7-10A

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FIG 4-19

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SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY
CONCENTRATION OF TOTAL VOLATILE ORGANICS IN
SUBSURFACE SOILS
POTENTIAL SOURCE AREA 7

CDM

environmental engineers, scientists,
planners, & management consultants

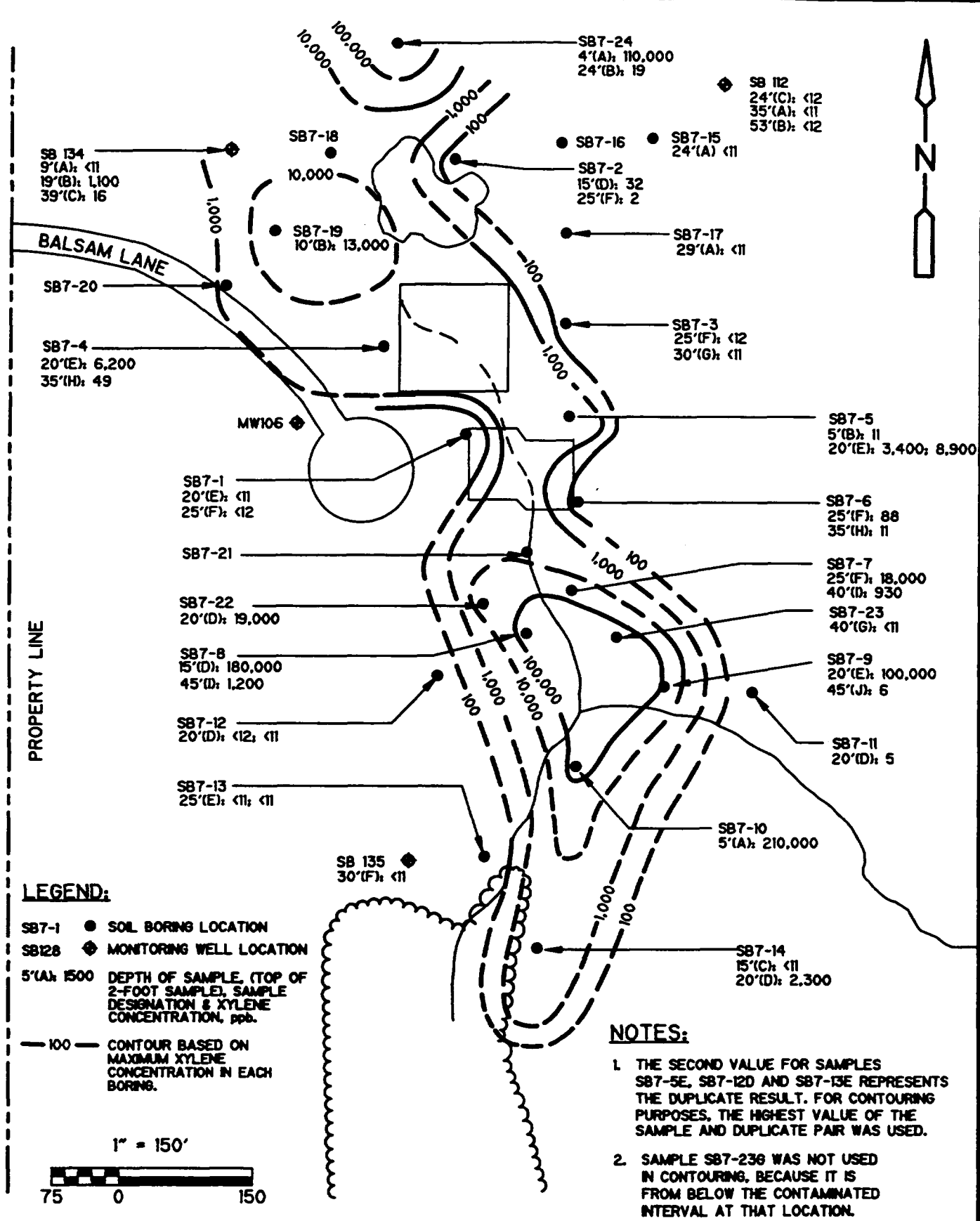
Figure No. 4-19

the peak concentration of xylene in Area 7 suggests that a NAPL may be present in a portion of Area 7. Using the same assumptions as were stated under PCE, a calculation of the concentration of xylene in the liquid portion of the subsurface sample yields $(1/0.30) \times 210 \text{ ppm} = 700 \text{ ppm}$. This concentration is higher than the sum of the solubilities of all three isomers of xylene (o-, m-, and p-xylene each have solubilities of 150 to 200 ppm), which is approximately 525 ppm. The higher concentration of xylene in sample SB7-10A suggests that a NAPL may exist at that hot spot location.

Xylene has a somewhat more limited distribution than that of chlorinated VOCs (see Figure 4-20). While the concentration of xylene is roughly similar to that of TCA and PCE in the hot spot contamination areas (generally within a factor of three), xylene concentrations are considerably less than those of TCA and PCE in borings away from the hot spots, such as at SB7-1, 7-2, 7-3, 7-11, 7-13, 7-17, SB134 (shallow sample A), and SB135. This contaminant distribution pattern is probably related to the ready biodegradation of xylene that occurs in an oxygenated environment (e.g., Chiang et al., 1989). The fringes of the contaminated soil volume (represented by the above-noted borings) are likely to exist in an oxygenated environment, based on the relatively shallow depth of the samples, and the relatively high air-permeability expected to prevail for most of the near-surface deposits, which are mainly sands and silts. Biodegradation of xylene at the margins of the hot spot contamination is also supported by groundwater contamination patterns: as discussed in subsection 4.8, xylene is relatively abundant in groundwater immediately downgradient of Area 7, but declines rapidly in the downgradient direction, making for a short contamination plume; this contrasts with the long contamination plumes formed by the chlorinated VOCs, which are more resistant to biodegradation in an oxygenated environment.

Toluene and ethylbenzene are two aromatic petroleum-derived compounds commonly associated with xylene, and were found to be locally abundant in the hot spot portions of Area 7. The concentration of toluene reached 23 ppm in both SB7-8D and SB7-10A, while ethylbenzene was reported at 31 and 26 ppm, respectively, in these two samples. In these and other hot spot areas, these compounds are present at roughly 10 to 20% the concentrations of TCA, PCE, and xylene. However, like xylene, the concentrations of toluene and ethylbenzene rapidly decline with distance away from the hot spots: they are present, if at all, at concentrations much less than 10% that of TCA and PCE at SB7-1, 7-3, 7-11, 7-13, 7-17, SB134 (shallow sample A), and SB135. A similar mechanism of biodegradation probably accounts for the contracted distribution of toluene and ethylbenzene in Area 7 subsurface soils as was proposed for xylene. Like xylene, toluene and ethylbenzene are relatively easily biodegraded in an oxygenated environment, conditions which are expected to prevail in the borings listed above. Biodegradation is discussed in detail in subsection 4.9.2, processes affecting contaminants in and near source areas. Again similar to xylene, toluene and ethylbenzene decline relatively rapidly in the groundwater contaminant plume downgradient from Area 7 (see subsection 4.8).

The presence of xylene, toluene, and ethylbenzene in Area 7 subsurface soils may be a result of their common use as solvents. For example, xylene is used as a solvent for alkyd resins, lacquers, enamels, and rubber cements; it is also used in protective coatings, in motor fuels, as a chemical intermediate, and in the manufacturing of dyes, pharmaceuticals, and insecticides. Toluene is used as a solvent for paints and coatings, gums, resins, adhesives, rubber, oils, and



SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY
XYLENE CONCENTRATION IN SUBSURFACE SOILS
POTENTIAL SOURCE AREA 7

vinyl compounds; it is also used in the manufacturing of caprolactum, saccharin, medicines, dyes, perfumes, benzoic acid, detergents, TNT, and other benzene derivatives; as a diluent and thinner for nitrocellulose lacquers; in aviation gasoline and high-octane blending stock; and in the preparation of toluenediisocyanate for polyurethane resins. Ethylbenzene is used as a chemical intermediate in the production of styrene, acetophenone, and other organic compounds, and as a resin solvent.

Benzene is commonly found with the other aromatic compounds xylene, toluene and ethylbenzene owing to its abundance in gasoline, and due to its chemical similarity to these compounds; however, benzene was not detected in any subsurface soil samples from Area 7. Contaminants in the Area 7 subsurface soils are probably not derived from the disposal or leakage of gasoline, based on the remote location of Area 7. Other uses of benzene include manufacture of numerous chemicals, and as a solvent. The lack of benzene in an area with high concentrations of other aromatic compounds may reflect what was initially disposed in Area 7; the other aromatic compounds have major uses as solvents, while solvent use is a relatively minor use for benzene owing to its established carcinogenicity.

The remaining VOC contaminants detected in subsurface soils in Area 7 are ketones (acetone, 2-butanone, and 4-methyl-2-pentanone), styrene, and carbon disulfide. Of these compounds, acetone was the most frequently detected and the most abundant, being reported from SB7-24A at 8,400 ppb. Acetone is employed in a wide variety of uses, including as a paint, varnish, and lacquer solvent, in cleaning and drying precision equipment, in sealants and adhesives, and as a chemical intermediate. Other detections of acetone were considerably lower: two of the other detections were 140 and 94 ppb, while all others were less than 30 ppb. The other compounds listed above were somewhat more limited in distribution than acetone; none were reported at concentrations above 15 ppb from more than one sample. For these and other low-concentration compounds, it should be noted that higher concentrations may be present in hot spots; however, such concentrations may be masked by the abundance of other compounds in these areas, which results in high detection limits. Overall, detections of the ketones, styrene, and carbon disulfide are relatively isolated in subsurface soils in Area 7. They have also not migrated significantly into groundwater (see subsection 4.8).

Tentatively Identified Compounds

A number of tentatively identified compounds (TICs) were reported from the VOC scan for subsurface soils in Area 7, primarily from samples with high VOC concentrations. For samples with total VOC concentrations of less than about 200 ppb, the concentration of total TICs generally ranged from undetected to 200 ppb. For samples with higher total VOC concentrations, the total concentration of TICs was greater than that of the total of identified VOCs by about a factor between two and six. Some of these TICs were specified, the most abundant of these being decane, ethylmethyl benzene isomer(s), and nonane; other alkanes or aromatic compounds were specified, but the largest remaining portion was unknown hydrocarbons.

A substantial quantity of TICs was also reported for the extractable semivolatile scan in many Area 7 subsurface soils. Extractable TICs were reported for all samples, but were most abundant

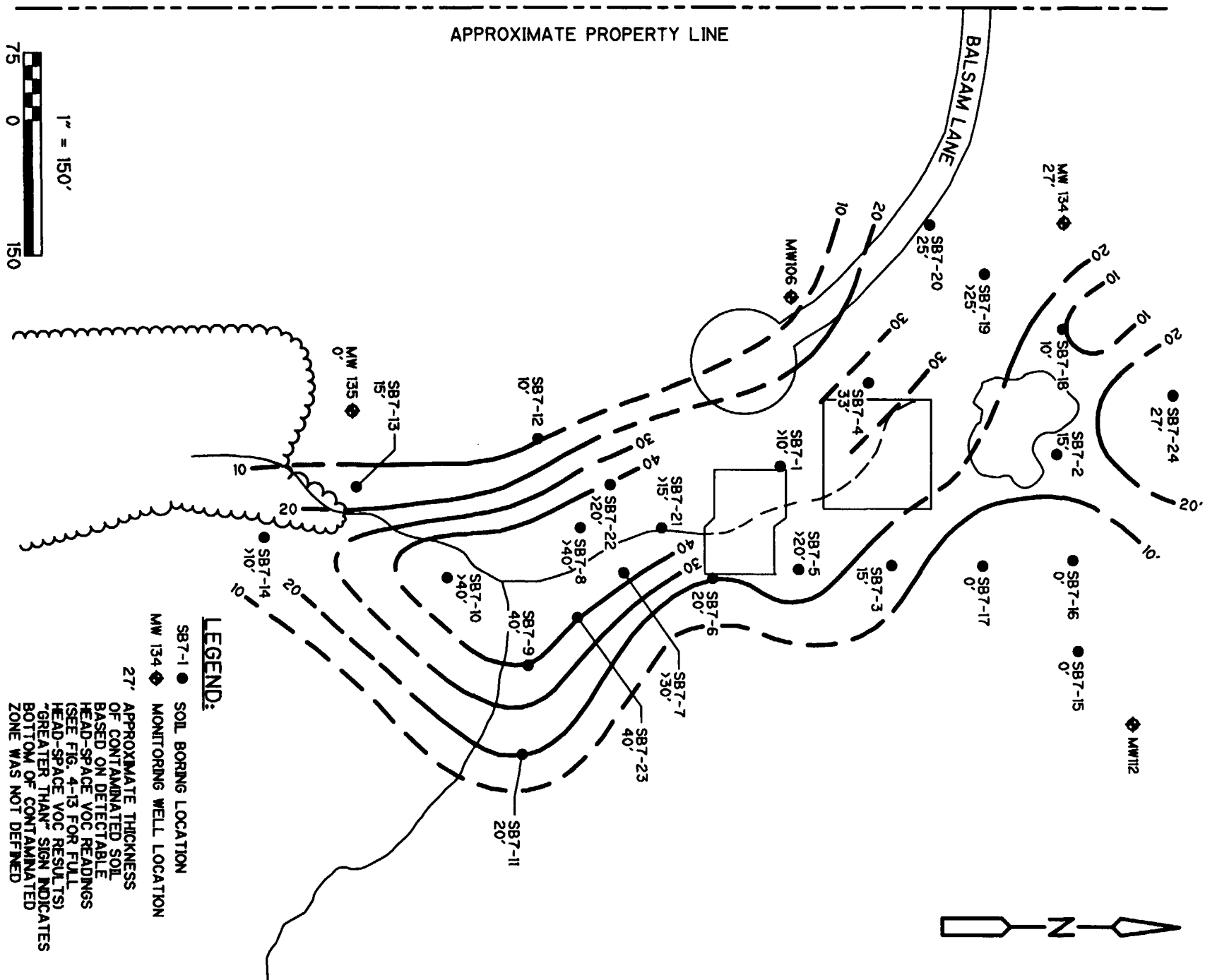
in samples with high VOC contamination. The total of extractable TICs generally correlates with that of total VOCs, and is generally greater than the total of the identified VOCs by a factor of about five to ten. The most abundant of the named extractable TICs were unspecified ethylmethyl benzene and trimethylbenzene isomers. Other aromatics, some alkanes and ketones were noted, but the largest fraction was generally described as unknown hydrocarbon compounds or simply unknown compounds.

Vertical Pattern of VOC Contamination in Area 7 Subsurface Soils

The vertical extent of subsurface soil VOC contamination in Area 7 can be obtained by referring to field head-space VOC readings; while no more than two subsurface soil samples were submitted for laboratory analysis, each sample from each boring was measured in the field for head-space concentration of VOCs. Comparison of head-space readings (Figure 4-13) with the concentration of total VOCs (Figure 4-19) shows that head-space readings correlate well with contaminant concentrations, and therefore provide an accurate indication of the vertical extent of contamination. Figure 4-21 presents the approximate thickness of the contaminated zone, based on the thickness of the zone with detectable VOCs based on head-space measurements. In general, the subsurface contaminated interval is thickest (about 40 feet) in the hot spot zone bounded by SB7-8, 7-9, 7-10, and 7-23. Three additional areas have contaminated intervals of about 20 to 30 feet: 1) north of the hot spot noted above and south of the basketball courts (at SB7-7, 7-21, and 7-22); 2) located near and northwest of the tennis courts (at SB7-4, 7-5, 7-19, and SB134); and 3) north of the playground (at SB7-24). The remaining subsurface sampling locations had contaminated intervals less than 20 feet thick; these locations also had significantly lower head-space and contaminant concentrations than the areas of greater thickness of contaminated soil. The resulting overall pattern of the vertical distribution of contamination in Area 7 subsurface soils is that the thickness of the contaminated interval is positively correlated with contaminant concentrations at a given location (compare Figure 4-21 with Figures 4-15 through 4-20).

Further examination of the vertical pattern of VOC contaminant concentrations in Area 7 borings reveals that detectable contaminant concentrations are primarily confined to the upper 40 or 45 feet of the subsurface. At each boring location, the peak contaminant concentrations (see Figures 4-15 through 4-20) and head-space measurements (see Figure 4-13) are within 25 feet of the ground surface; these measurements show sharp declines within 15 to 30 feet below the interval of peak concentration. Figure 4-13 also indicates which samples are saturated; comparison with Figure 4-19 shows that the highest VOC concentrations are consistently located in the upper portion of the saturated zone, or just above the saturated zone.

The high-contamination zone (suspected NAPL zone) in Area 7 is smaller than the total volume of contaminated soil, as might be expected. In order to estimate the thickness of the likely contaminated zones in Area 7, the results of field head-space screening are most useful. Though the appearance of a dark, oily phase in soil samples is also useful in assessing the presence and extent of areas of high VOC concentration and potential residual NAPLs, in Area 7 this method alone is insufficient for two reasons: 1) the color of high-contamination samples in Area 7 vary considerably, with some samples being dark gray, but many more being a grayish or brownish color (the latter appears similar to uncontaminated sands); and 2) a dark color can arise from



SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY

CDM

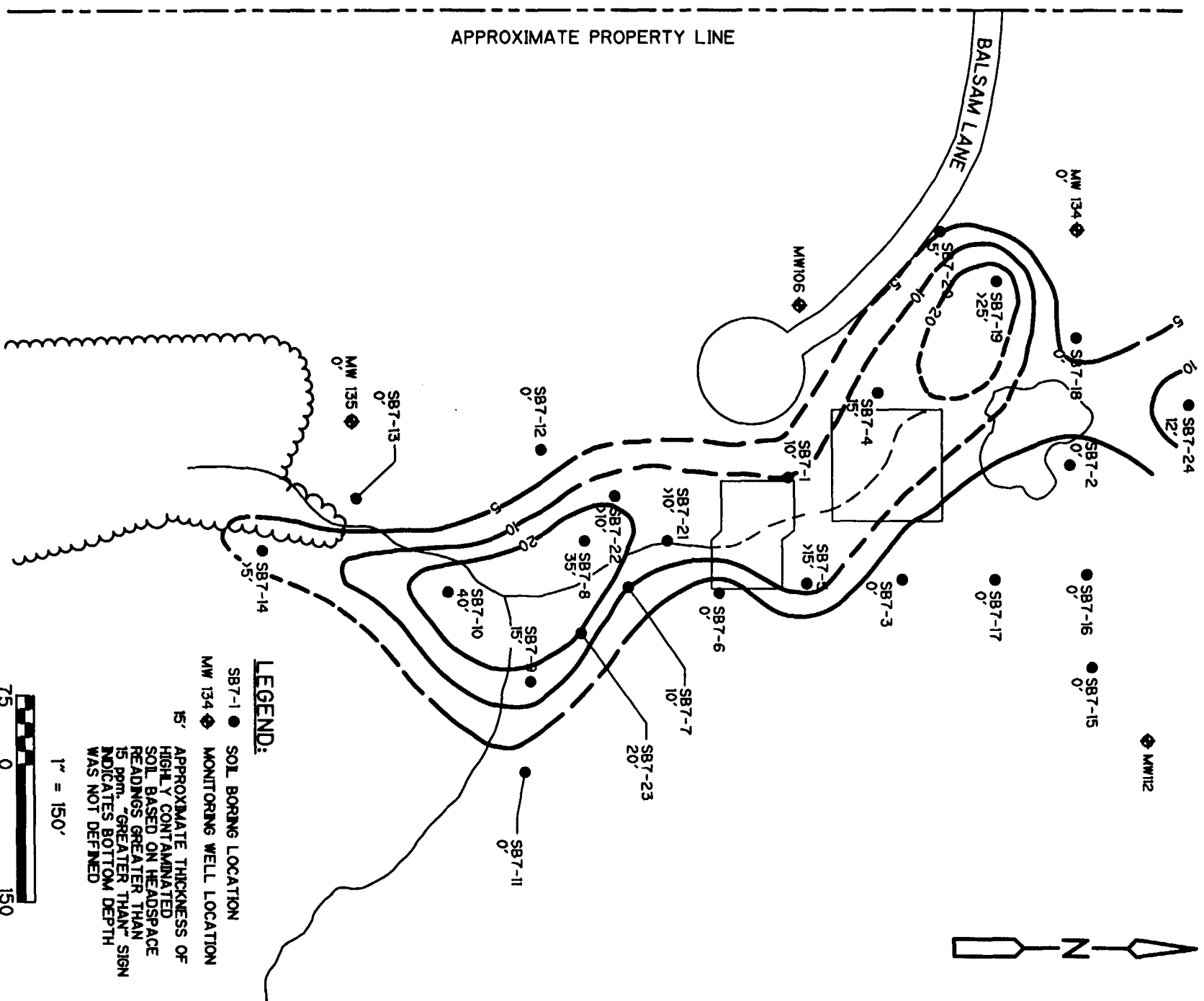
environmental engineers, scientists,
planners, & management consultants

**APPROXIMATE THICKNESS OF VOC-CONTAMINATED SOILS
IN POTENTIAL SOURCE AREA 7**

the former presence of an oily phase, such that the primary remaining contaminants could be the dark-hued PAHs. As a result, the most useful data collected in Phase II to indicate areas with high VOC concentrations in soil in Area 7 is head-space VOC screening.

Head-space VOC screening results for subsurface soil samples in Area 7 correlate very well with analytical results. For the 11 samples with measured head-space concentrations greater than 15 ppm, all but two had analytical results for total VOCs of greater than 10 ppm (ranging from 20 ppm to 1,019 ppm). Of the 21 samples with head space concentrations less than 15 ppm, all 21 had analytical results for total VOCs less than 10 ppm (ranging up to 3.4 ppm). Based on this relationship, the presence and thickness of highly contaminated zones can be estimated for each boring. Using the 15 ppm threshold to indicate these zones, Figure 4-22 was constructed to provide an approximate thickness of zones of high VOC contamination across Area 7. This figure shows that there is one long, irregularly-shaped area centered on the basketball courts where residual NAPL contamination may be present. Comparison of this figure with the figures showing results for specific contaminants (Figures 4-15 through 4-20) shows that the areas with high headspace readings generally match the areas of highest contamination for each contaminant. The thickest interval of VOC contaminated soil is about 40 feet at SB7-10, where all samples collected between five and 40 feet had head-space measurements of 15 ppm or higher. This information should be used to develop a conceptual NAPL model to guide future source area studies.

Another important characteristic of subsurface soil VOC contamination in Area 7 is that contamination is largely distributed irrespective of subsurface stratigraphy. As shown in the cross-sections presented in Figures 3-8 and 3-9, high head-space results (and corresponding analytical results) are present in silty units as well as in sandy units. In fact, some of the highest head-space and contaminant concentrations are present in the silty units, such as at SB7-5, 7-9, 7-10, 7-21, 7-22, and 7-23. Currently, the primary vertical control on contaminant distribution appears to simply be the depth of saturation, with the highest concentrations appearing near this depth. The penetration of contamination into lower-permeability units such as sandy silts and clayey silts (at SB7-9 and SB7-21, the middle portions of five-foot thick clayey silts have very high concentrations) probably relates to the long period of time available for the non-aqueous phase contaminants to migrate into them. As the majority of the contaminants detected in Area 7 are not miscible with water, and apparently lighter than water (or with density similar to that of water), much of the contaminant mass has likely remained on top of the saturated zone (possibly as residual NAPL) beneath the point of disposal for an extended period of time. Some dispersal of the original contamination may have occurred along the upper portion of the shallow silt layers which underlie the area (see Figures 3-8 and 3-9), however, much of the contaminant mass appears to have remained in the same vicinity as it was shortly after disposal, owing to the relatively low solubility in water (1,200 pm or less) of the compounds detected in the area. It should be noted that the perched conditions in Area 7 would have affected the contaminant distribution shortly after disposal by causing the contamination to move horizontally along the top of low permeability zones such as silt layers. Over time, though, extensive VOC penetration into the low permeability layers would have occurred, as indicated by the high head-space and contaminant concentrations in the silty units. Under such conditions of extended residence time, any NAPL that might be present could easily penetrate into lower-permeability units such as sandy silts and clayey silts.



SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY

**APPROXIMATE THICKNESS OF HIGHLY CONTAMINATED
SOIL IN POTENTIAL SOURCE AREA 7**

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The pattern of contamination in the vadose zone that has been established in Area 7 is that hot spots exist which contain light NAPL compounds whose distribution is controlled primarily by the depth of saturation, rather than by stratigraphy; where silty units are present at or near the water table, these units have become highly contaminated. At this time, the presence of residual NAPL in the vadose zone has not been confirmed. Future source studies will need to evaluate and verify these hypotheses, particularly as they relate to potential remediation, because cleanup of a NAPL mass in a silty unit will require considerably more time than cleanup of NAPL in a sandy interval.

The data collected during Phase I and Phase II for Area 7 and anecdotal disposal information indicate that in addition to the potential for the presence of residual NAPL zones at or above the water table, the possibility exists for DNAPL zones at depth within the saturated zones. As in Area 4, no soil borings or wells were completed within the hot spots at depths sufficient to detect any DNAPL zones. None of the wells completed to the north or west of Area 7 contained visible DNAPL. Future source studies should make use of the existing Area 7 data to develop a conceptual model and phased investigation approach. Of primary importance for future studies would be minimizing the risks of spreading any NAPL contamination that may be present.

Volume of Contaminated Subsurface Soils in Area 7

A rough estimate of the volume of contaminated soil can be obtained by using the contoured subsurface soil data in concert with the thickness of the contaminated subsurface interval. For the case of TCA, Figure 4-15 was used by first measuring the area occupied by each strip of land between individual contours. Within each of these four areas, an average value was calculated for TCA concentration and for thickness of the contaminated interval (the latter was compiled using Figure 4-13). The resulting volume of subsurface soils with TCA contamination above 100 ppb is approximately 260,000 yd³, and the total mass of TCA in these soils is approximately 6150 kilograms.

These estimates are crude, however, for several reasons: 1) the area underlain by contaminated soils has not been completely delineated, particularly to the north and the northwest - the isolated occurrence of high contaminant concentrations at SB7-24 suggests that other local hot spots may exist to the north of the area investigated; 2) the concentration of TCA and other VOCs in subsurface soils is highly variable, particularly in samples with the highest concentrations - even duplicate samples display significantly different values than corresponding investigative samples, probably due to the natural variability in subsurface soils, which in turn influences contaminant abundance; and 3) the continuity of subsurface contamination between borings is not known with certainty - significant variability is expected across distances of 70 to 125 feet, the typical distance between borings. The second and third items above are particularly significant, because different estimates of contaminant abundance in the high-contaminant zones have an overwhelming effect on total estimated contaminant volumes. As a result, the estimates of contaminated soil volume and, particularly, contaminant volume, are only first-order approximations. More reliable estimates would require additional borings at closer intervals across this extensive source area.

Comparison with Soil Gas and Geophysical Surveys

The results of subsurface soil sampling compare well with the results of soil gas sampling in Area 7. Comparison of the subsurface sampling results (see Figures 4-15 through 4-17) with the soil gas sampling results (see Figures 4-5 through 4-7) reveals that both sampling efforts display north-south zones of elevated contaminant concentrations centered near the basketball courts; in both media, especially high concentrations exist from about 100 feet south of the confluence of the two small valleys (near SB7-10) to near the tennis courts (near SB7-4 and 7-5). Both surveys show high-PCE zones (relative to TCA and TCE) near the southern part of the grid (near SB7-14). The proportions of target compounds in the two media are somewhat different, however. In particular, PCE is much less abundant relative to TCA in soil gas (ratios of PCE to TCA are generally between 0.02 and 0.40, including the hot spot near SB7-8) than in subsurface soils (ratios of PCE to TCA are generally between 0.08 and 2.7, including the hot spot near SB7-8). This contrast is probably a function of higher vapor pressure for TCA (100 mm at 20 C) than for PCE (14 mm at 20 C). As a result, TCA will tend to volatilize much more readily from contaminated subsurface soils (most of the contamination is at least 10 to 15 feet below the ground surface) than PCE. Consequently, in comparing soil gas samples to underlying contaminated subsurface soils, proportionally higher results for TCA relative to PCE would be expected, which is what is observed in Area 7.

The results of subsurface soil sampling in Area 7 affirm that the width of the high-contamination zone in the subsurface is about 100 feet, considerably wider than the geophysical anomalies (about 40 feet). The subsurface soil sampling also indicates that the depth of the high-contamination zone generally occupies an interval beginning near the water table and extending a limited distance (approximately 10 to 20 feet) below the water table. The shallow contaminant distribution is consistent with the hypothesis that a light NAPL may be present as residual, which could help account for the greater width of the high-contaminant zone compared to the geophysical anomalies, in the manner described below. During periods of water-table fluctuation, contaminants present near the water table would be expected to move to a limited degree. While the contamination consists of oily, non-aqueous phase liquids that do not mix extensively with groundwater, such migration is still expected to take place, because this contamination would tend to exist at or above the water table. Much of this migration would be vertical, but some horizontal movement is also likely. The net result is a smearing out of the high-contaminant zone across a wider area than that occupied by the wastes shortly after disposal. In contrast, solid metallic materials, such as cans and other debris observed in the former stream valleys in Area 7, would remain in place during fluctuation of the water table. As a result, geophysical anomalies, which reflect the distribution of buried metals, would show the same narrow distribution of metallic material as its initial position of disposal.

Extractables, Pesticides, PCBs, and Inorganics

A number of extractable semivolatiles, pesticides, and PCBs were detected in subsurface soils in Area 7. For the extractables, most of the detections, including all of the highest concentrations, were in the hot spot NAPL zones. Full subsurface soil sampling results for extractables in Area 7 are presented in Appendix H-5. These include naphthalene (up to 15,000 ppb; highest value detected at SB7-10A), 2-methylnaphthalene (up to 10,000 ppb; SB7-10A), di-n-butylphthalate (up

to 2,100 ppb; SB7-10A), diethylphthalate (up to 1,800 ppb; SB7-7F), 2,4-dinitrotoluene (1,500 ppb, detected at SB7-10A only), bis(2-ethylhexyl)phthalate (up to 1,200 ppb; SB7-24A), and isophorone (880 ppb; SB7-24B only). Naphthalene is a commonly used chemical employed as an intermediate in the production of various chemicals, in mothball manufacturing, in preparation of pesticides, dyes, detergents, wetting agents, and lubricants, among other uses; it is found naturally in petroleum and coal. The compound 2-methylnaphthalene is used in organic synthesis and insecticides; like naphthalene, it is a PAH and is therefore found in petroleum and coal, and is commonly present in waste oils. Di-n-butylphthalate is a plasticizer that is also used in insect repellants and organic synthesis. Diethylphthalate is a widely used chemical employed as a plasticizer, in plastic manufacturing and processing, as an ingredient in insect sprays and explosives, as a denaturant for ethyl alcohol, as a dye application agent and a wetting agent. The compound 2,4-dinitrotoluene is used in organic synthesis and as an intermediate for toluidine, dyes, and explosives. Bis(2-ethylhexyl)phthalate is a plasticizer that is also used in vacuum pumps. Isophorone is used as a solvent for paints, vinyl resins, tin coatings, agricultural chemicals and cellulose esters; in pesticide manufacturing; and in storing lacquers.

The occurrence of the various extractable compounds detected in the subsurface soil hot spots is consistent with the concept that the hot spots formed through the disposal of oily wastes, solvents, and possibly pesticides. Detections of extractable compounds outside the hot spot zones were low or non-existent for all these compounds; as discussed in the groundwater subsection (4.8), none of these compounds has migrated to any great extent into groundwater downgradient from Area 7. The presence of phthalates may not be due to disposal of these compounds per se, but to the existence of phthalates in plastics, which are likely to be abundant in the assorted wastes present in the Area 7 disposal area. The phthalates are most abundant in the samples containing high concentrations of compounds capable of dissolving them, such as xylene, toluene, and chlorinated solvents (such as SB7-7F, SB7-10A, and SB7-24A); the presence of the higher phthalate concentrations in these samples may be due to their enhanced solubility in such samples.

The pesticides have a distinctive distribution in subsurface soils in Area 7, with all the detections occurring in two areas: the southern end of the area sampled (at SB7-14 and SB135) and the northern end (at SB7-24). The highest detections were methoxychlor (up to 33 ppb; highest value detected at SB7-24B), aldrin (15 ppb, detected at SB7-14D only), 4,4'-DDE (up to 12 ppb; SB7-14D), -chlordane (9.8 ppb; SB7-14D only), and endosulfan II (6.2 ppb; SB7-14D only); other compounds were detected at less than 5 ppb, and in one or two samples. Detections of pesticide compounds outside the noted locations were low or non-existent for all these compounds; as discussed in the groundwater subsection (4.8), none of these compounds has migrated to any great extent into groundwater downgradient from Area 7. Full subsurface soil sampling results for Area 7 pesticides are presented in Appendix H-5.

Detections of PCBs in subsurface soils in Area 7 were mainly in the central portion of the area sampled, from SB7-1 to SB7-9. The highest PCB concentrations were in the hot spot zones: aroclor-1254 was detected at up to 2,500 ppb (highest concentration was at SB7-9E), and aroclor-1232 at up to 490 ppb (highest at SB7-8D); other detections were at SB7-14D (aroclor 1254 at 430 ppb) and near the hot spots at SB7-5E (aroclor-1242 at 170 ppb) and at SB7-1E (aroclor-1260 at 58 ppb). Detections of PCBs outside the noted locations were low or non-existent for all these

compounds; as discussed in the groundwater subsection (4.8), none of these compounds has migrated to any great extent into groundwater downgradient from Area 7. Full subsurface soil sampling results for Area 7 PCBs are presented in Appendix H-5.

As might be expected, a number of inorganic constituents were detected in subsurface soils in Area 7 (full subsurface soil sampling results for Area 7 inorganics are presented in Appendix H-6). However, most inorganics do not display particularly high variability across Area 7 or in comparison to subsurface soil samples from areas apparently not impacted by contamination. Most of the variation between samples is a function of the natural differences in composition of silts and clays versus that of sands and gravels. Silty and clayey samples such as SB7-1E, 7-4E, 7-6F, 7-9J, 7-14C, and 7-24B consistently have higher concentrations of aluminum, arsenic, barium, copper, lead, potassium, and zinc than sandy and gravelly samples such as SB7-3F, 7-7I, and 11D, and samples from Areas 2, 4, 11, and 14 (see boring logs in Appendix A for the full listing of subsurface soil sampling depths and sample characteristics).

Results from samples at locations believed to be unaffected by inorganic contamination (SB112, SB7-15, SB133) can be used to estimate local background levels for the various naturally-occurring inorganic constituents. At location SB7-10A and SB7-24A, results for several inorganics are higher than these estimated background concentrations by factors of greater than two, as well as being considerably higher than the typical values found in soils of the eastern United States (Shacklette and Boerngen, 1984). These constituents are copper (45.7 ppm at SB7-10A, versus estimated background of less than or equal to 15 ppm), lead (88.6 ppm at SB7-10A; background 7 ppm), mercury (0.73 ppm at SB7-10A; background below detection limit of 0.12 ppm), selenium (1.3 ppm at SB7-24A; background below detection limit of 0.25 ppm), and zinc (80.2 ppm at SB7-10A; background 30 ppm). In addition, cyanide was detected at SB135F at a concentration of 1.3 ppm (background estimated to be below detection limit of 0.12 ppm). Elevated levels of inorganic constituents such as these are commonly noted in waste solvents and oils; their concentrations in NAPL samples (SB7-10A, SB7-24A) are consistent with the postulated waste solvent or waste oil origin of the NAPL material. As discussed in the groundwater subsection (subsection 4.8), none of these constituents has migrated significantly in groundwater downgradient from Area 7; cyanide shows limited mobility only.

4.5.1.4 Area 9

One subsurface boring was drilled and sampled in Area 9 (see Figure 4-23) to investigate the existence of VOC contamination at a location with moderately elevated detections of target compounds in soil gas (TCA, PCE, and TCE at 91 to 120 µg/L). Additional borings were not possible due to the presence of utilities. In this boring (SB9-1), none of the subsurface soil samples displayed detectable VOCs in field head-space screening, and there was no visual evidence of contamination in any sample. Based on the lack of response in head-space screening, one sample was selected for laboratory analysis (the sample nearest to and above the water table); a duplicate was also collected. For volatiles and semivolatiles (which include extractables, pesticides, and PCBs), PCE was the only compound detected, at a concentration of 5 ppb in both sample and duplicate. The detection of PCE in subsurface soil is consistent with its detection in the soil gas sample. This one data point is not sufficient to evaluate any contributions to groundwater contamination from potential sources within the area.

The soil gas samples and the one soil boring in Area 9 were located in the western portion; access problems precluded investigation of the eastern part of Area 9. As the elevated soil gas concentrations were not closed off to the east, the eastern part of Area 9 remains suspect. There is insufficient data from the western portion of Area 9 to fully evaluate any contaminant source of VOCs to groundwater. Area 9 was retained for further investigation as a potential contaminant source. Further work included installation of monitoring wells at four locations (MW123, MW124, MW125 and the MW126 nest), MW123 and MW124 are downgradient from the western portion of Area 9 and MW125 and the MW126 nest are located roughly downgradient (southwest) of the eastern part of Area 9.

4.5.1.5 Area 11

Subsurface soil sampling was conducted in Area 11 to investigate an area with reports of elevated petroleum-related compounds and chlorinated VOCs in soils and groundwater. Due to access limitations, soil gas sampling was conducted only in the southwestern part of Area 11 in Phase II of the RI, in the parking lot of the Villa da Roma Restaurant (formerly part of the Rockford Varnish facility). Though no elevated concentrations of the target compounds, TCE, PCE and TCA were detected in this area, these samples were collected south of the area with the reported contaminant releases (based on responses to USEPA 104E requests). As a result, when access was acquired to the northern part of Area 11, subsurface soil sampling was conducted across the latter area. This northern area comprises the former railroad right-of-ways south of the current Rohr Manufacturing building (and north and northeast of the soil gas samples at Villa da Roma).

Eleven subsurface borings were drilled and sampled in Area 11, including one in which well MW128 was installed. Subsurface soil sampling in Area 11 showed contaminated soils across a broad area. As shown in Table 4-4, all borings in Area 11 except SB11-2 and 11-3 had samples with elevated organic vapor concentrations based on head-space field screening; these samples also showed olfactory and visual evidence of contamination by an oily product.

Analytical results and head-space screening for the subsurface soil samples show that there are two distinct areas of VOC contamination in Area 11 (western and eastern), separated by a central zone with relatively low contaminant concentrations. Though the proportions differ, VOC contamination in both areas is dominated by the aromatic compounds toluene, ethylbenzene, and xylene, (ETX) generally at very high concentrations ranging up to 1,400 ppm, 590 ppm, and 2,200 ppm, respectively. The abundance of these compounds in Area 11 may result from their common uses in paint thinners and in solvents for paints, coatings, and varnishes; this is consistent with the former use of the Rockford Varnish property to the south. In addition to the aromatic compounds noted, moderate concentrations (410 to 2,200 ppb) of methylene chloride, benzene, and TCE were reported from one sample each, and relatively low concentrations (less than 50 ppb) were reported for several other compounds, including acetone, methylene chloride, TCA, and carbon disulfide (see Figure 4-24). It is possible that the high concentration of ETX compounds has masked the presence of other VOCs, such as chlorinated compounds. The samples with high ETX levels were diluted and have elevated detection limits, so ppb levels of other VOC would not have been detected.

TABLE 4-4
Summary of Subsurface Soil Sampling Results, Area 11

Sample Number	Depth, feet ¹	Organic Vapors, ppm: scan/head space ³	Analytical Results ²	
			Total VOCs, ppb	Total Chlorinated VOCs, ppb
SB11-1A	5-7	-/0	--	--
SB11-1B	10-12	-/0	--	--
SB11-1C	15-17	-/0	--	--
SB11-1D	20-22	-/0	--	--
SB11-1E	25-27	4.2/0.4	--	--
SB11-1F	30-32 *	3.3/0.9	--	--
SB11-1G	35-37 *	90.5/134.4	1,186,000	N.D.
SB11-1H	40-42 *	26.7/16.6	--	--
SB11-1I	45-47 *	13.3/0.4	--	--
SB11-1J	50-52 *	0/0	214; 1	13; 1
SB11-2A	5-7	0/0	--	--
SB11-2B	10-12	0/0	--	--
SB11-2C	15-17	0/0	--	--
SB11-2D	20-22	0/0	11	N.D.
SB11-2E	25-27 *	0/0	--	--
SB11-2F	30-32 *	0/0	--	--
SB11-3A	5-7	0/0	--	--
SB11-3B	10-12	0/0	--	--
SB11-3C	15-17	0/0	--	--
SB11-3D	20-22 *	0/0	69	49
SB11-3E	25-27 *	0/0	--	--
SB11-3F	30-32 *	0/0	--	--

Sample Number	Depth, feet ¹	Organic Vapors, ppm: scan/head space ³	Analytical Results ²	
			Total VOCs, ppb	Total Chlorinated VOCs, ppb
SB11-4A	5-7	0/0	--	--
SB11-4B	10-12	0/0	--	--
SB11-4C	15-17	0/0	--	--
SB11-4D	20-22	0/0	--	--
SB11-4E	25-27 *	0/0	--	--
SB11-4F	30-32 *	20/45	--	--
SB11-4G	35-37 *	233/247	307,000	N.D.
SB11-4H	40-42 *	40/57	--	--
SB11-4I	45-47 *	8/34	--	--
SB11-4J	50-52 *	8/27	--	--
SB11-4K	55-57 *	0/7	--	--
SB11-4L	60-62 *	0/1.5	97	5
SB11-5A	5-7	0/0	--	--
SB11-5B	10-12	0/0	--	--
SB11-5C	15-17 *	14.3/3.2	--	--
SB11-5D	20-22 *	1.8/4.6	--	--
SB11-5E	25-27 *	3.6/9.2	--	--
SB11-5F	30-32 *	16.6/7.4	--	--
SB11-5G	35-37 *	102/86.8	--	--
SB11-5H	40-42 *	120/87.5	910,000	N.D.
SB11-5I	45-47 *	1.8/9.2	--	--
SB11-5J	50-52 *	0.4/2.3	--	--
SB11-5K	55-57 *	0.9/2.7	760	N.D.

¹ - Asterisk indicates sample is saturated

² - Second value refers to result for duplicate sample

³ - Readings measured with OVM

TABLE 4-4 (continued)
Summary of Subsurface Soil Sampling Results, Area 11

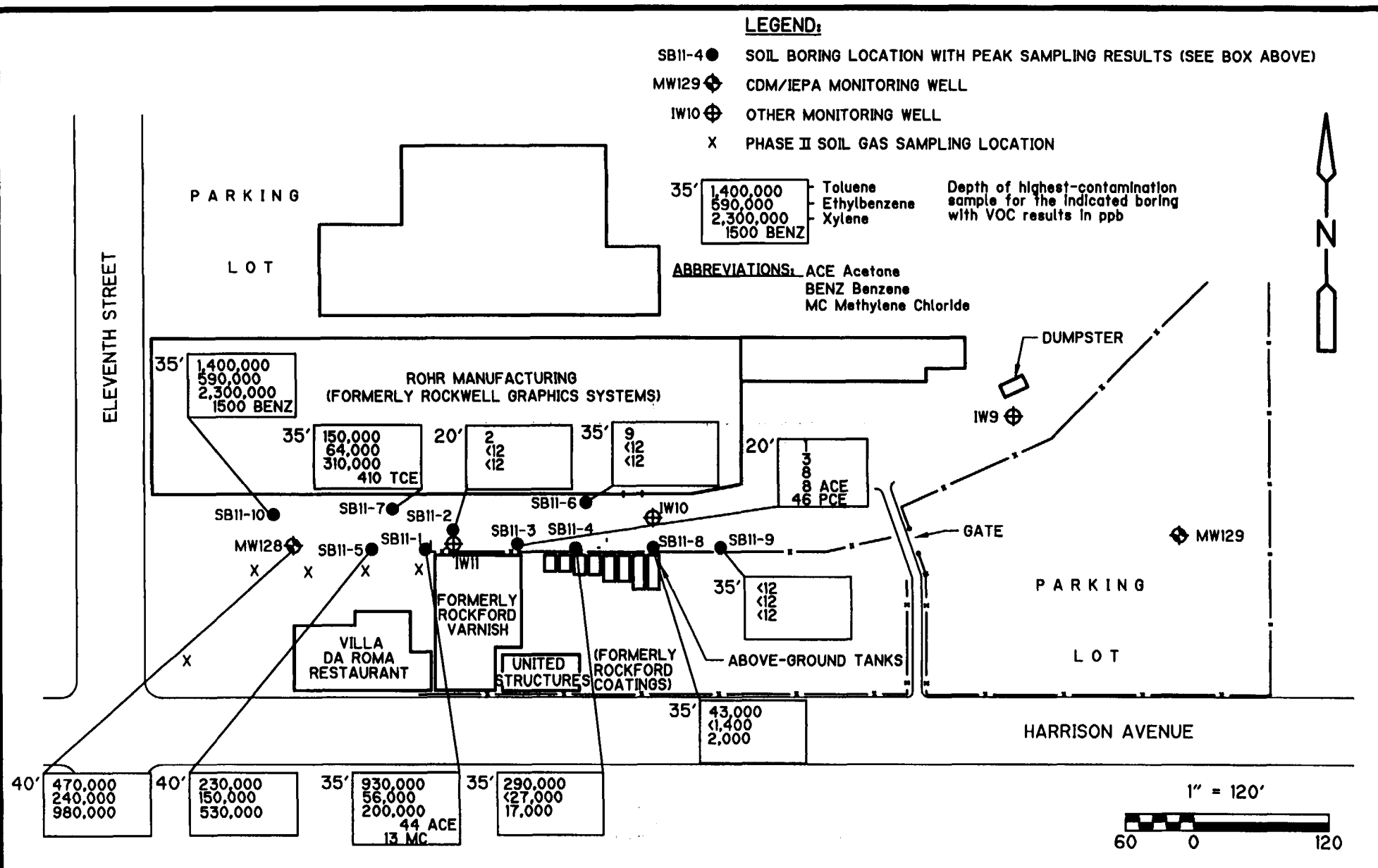
Sample Number	Depth, feet ¹	Organic Vapors, ppm: scan/head space ³	Analytical Results ²	
			Total VOCs, ppb	Total Chlorinated VOCs, ppb
SB11-6A	5-7	0/0	--	--
SB11-6B	10-12	0/0	--	--
SB11-6C	15-17	0/0	--	--
SB11-6D	20-22 *	0/0	--	--
SB11-6E	25-27	0/0	--	--
SB11-6F	30-32 *	0/3.2	--	--
SB11-6G	35-37 *	79.9/40.2	40	24
SB11-6H	40-42 *	20.9/33.1	--	--
SB11-6I	45-47 *	0/0.4	42	33
SB11-7A	5-7	0/0	--	--
SB11-7B	10-12	0/0	--	--
SB11-7C	15-17	0/0	--	--
SB11-7D	20-22	0/0	--	--
SB11-7E	25-27	0/-	--	--
SB11-7F	30-32 *	3.2/330	--	--
SB11-7G	35-37 *	>1000/>1000	524,410	410
SB11-7H	40-42 *	>1000/>1000	--	--
SB11-7I	45-47 *	20.8/79.9	--	--
SB11-7J	50-52 *	43.5/91.9	--	--
SB11-7K	55-57 *	8.0/53.3	13	N.D.
SB11-8A	5-7	0/0	--	--
SB11-8B	10-12	0/0	--	--
SB11-8C	15-17	0/0	--	--
SB11-8D	20-22	0/0	--	--
SB11-8E	25-27 *	0/0	--	--
SB11-8F	30-32 *	0/11.2	--	--
SB11-8G	35-37 *	2510/394	47,200	2,200
SB11-8H	40-42 *	30.6/3.2	--	--
SB11-8I	45-47 *	1.6/9.6	2,100; 2,900	2,100; 2,900

Sample Number	Depth, feet ¹	Organic Vapors, ppm: scan/head space ³	Analytical Results ²	
			Total VOCs, ppb	Total Chlorinated VOCs, ppb
SB11-9A	5-7	0/0	--	--
SB11-9B	10-12	0/0.4	--	--
SB11-9C	15-17	0/0.8	--	--
SB11-9D	20-22	0/0.4	--	--
SB11-9E	25-27 *	0/0.4	--	--
SB11-9F	30-32 *	0/1.3	--	--
SB11-9G	35-37 *	0/4.4	56	53
SB11-9H	40-42 *	0/4.4	--	--
SB11-10A	5-7	0/0	--	--
SB11-10B	10-12	0/0	--	--
SB11-10C	15-17	0.7/0.1	--	--
SB11-10D	20-22	3.2/0.1	--	--
SB11-10E	25-27	5.0/0.4	--	--
SB11-10F	30-32 *	13.0/5.6	--	--
SB11-10G	35-37 *	500/320	4,291,500	N.D.
SB11-10H	40-42 *	450/280	--	--
SB11-10I	45-47 *	20.0/11.0	--	--
SB11-10J	50-52 *	1.5/18.0	39	N.D.
SB128	5-7	-/0	--	--
SB128	10-12	-/3.2	--	--
SB128	15-17	-/6.4	--	--
SB128	20-22	-/5.4	--	--
SB128	25-27 *	-/3.8	--	--
SB128	30-32 *	-/5.0	--	--
SB128	35-37 *	-/200	--	--
SB128A	40-42 *	-/300	1,690,000	N.D.
SB128	45-47 *	-/35	--	--
SB128	50-52 *	-/30	--	--
SB128B	55-57 *	-/6.0	258	N.D.
SB128	60-62 *	-/4.0	--	--

¹ - Asterisk indicates sample is saturated

² - Second value refers to result for duplicate sample

³ - Readings measured with OVM, except for samples from 20 through 62 feet at MW128



SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY
SUBSURFACE SOIL SAMPLING RESULTS
POTENTIAL SOURCE AREA 11

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Figure No. 4-24

The western and eastern portions of Area 11 appear to have different chemical signatures. In the western zone, ethylbenzene was detected in each boring and xylene was generally more abundant than toluene (about twice the concentration of toluene in four of the five borings; in the fifth, xylene was about 20% the concentration of toluene; see Figure 4-24). In the two borings with high detections in the eastern portion, however, toluene was by far the most abundant contaminant, with xylene being detected at about 5% of the concentration of toluene; in addition, ethylbenzene was not detected in either boring. The western portion of Area 11 appears to constitute a contiguous source of contamination by aromatic VOCs. The extent of this contaminated area is not known to the north, west, and south, because of access and structural limitations on drilling. However, based on the distribution of VOCs observed in soil borings as illustrated in Figure 4-24, the minimum size of the western high-contamination portion of Area 11 is an east-west rectangle with dimensions of about 30 by 120 feet. The eastern contaminated portion of Area 11 appears to be smaller than the western, though the southern and northeastern limits are not known; if contamination does not extend far in either of these directions, then the dimensions of this contaminated area would be roughly 40 by 80 feet.

The depth of the contaminated soil volume in Area 11 can be estimated from the field head-space measurements. While only one or two samples per boring were submitted for laboratory analysis, head-space measurements were collected for all subsurface samples collected, and therefore provide the best indicator of the vertical extent of contamination. Though head-space measurements were detectable for many samples, only those samples with head-space measurements greater than 75 ppm correlated with very high contaminant concentrations based on analytical results (greater than 40,000 ppb of total VOCs; see Table 4-4). All the samples with head-space results less than 75 ppm correlated with relatively low contaminant concentrations (less than 3,000 ppb total VOCs). Given the correlations observed between head-space results and associated analytical results, the vertical extent of the high-contamination zone was estimated based on the approximate thickness of the zone with head-space concentration greater than 75 ppm, and is shown on Table 4-4. This interval ranges from zero to 25 feet thick across Area 11, and is zero to 10 feet thick in 10 of the 11 borings (see Table 4-4). This high-concentration zone generally encompasses the interval from about 32.5 to 37.5 feet but is also observed between 40 and 42 feet at SB11-128 and SB11-5. During drilling, the water table was at a depth of about 24 to 28 feet in Area 11; however, Area 11 drilling was conducted in August 1993, when water levels were still somewhat higher than normal in the aquifers. Measurements collected at other times (October 1993 CDM water level survey and ISWS surveys) show that the water table is typically at about 30 feet. As shown in Table 4-4, head-space results decline at all locations with increasing depth below the water table. The composition and vertical pattern of the high contamination zone in Area 11 suggests the possibility of light NAPL (LNAPL) residual with minor DNAPL components. No specific testing was performed in Phase II to characterize or confirm the suspected NAPL near the water table. Monitoring wells were not screened at the water table interface in Area 11 so the presence of NAPL in wells could not be evaluated. The presence of residual NAPL is suspected based on the common presence of sticky, gray zones in the samples with high head-space results. In addition, concentrations of toluene and xylene (up to 1,400 ppm and 2,200 ppm, respectively) are higher than the solubilities of these compounds in water (515 and about 200 ppm, respectively). Based on the general lack of visible organic carbon in the sands of this area, sorption is not likely to account for the excess of these compounds above their water-solubilities; residual NAPL is a likely explanation for the high contaminant

concentrations. The high concentration of aromatic compounds in subsurface soils from Area 11 is consistent with the derivation of the contamination from varnish disposal.

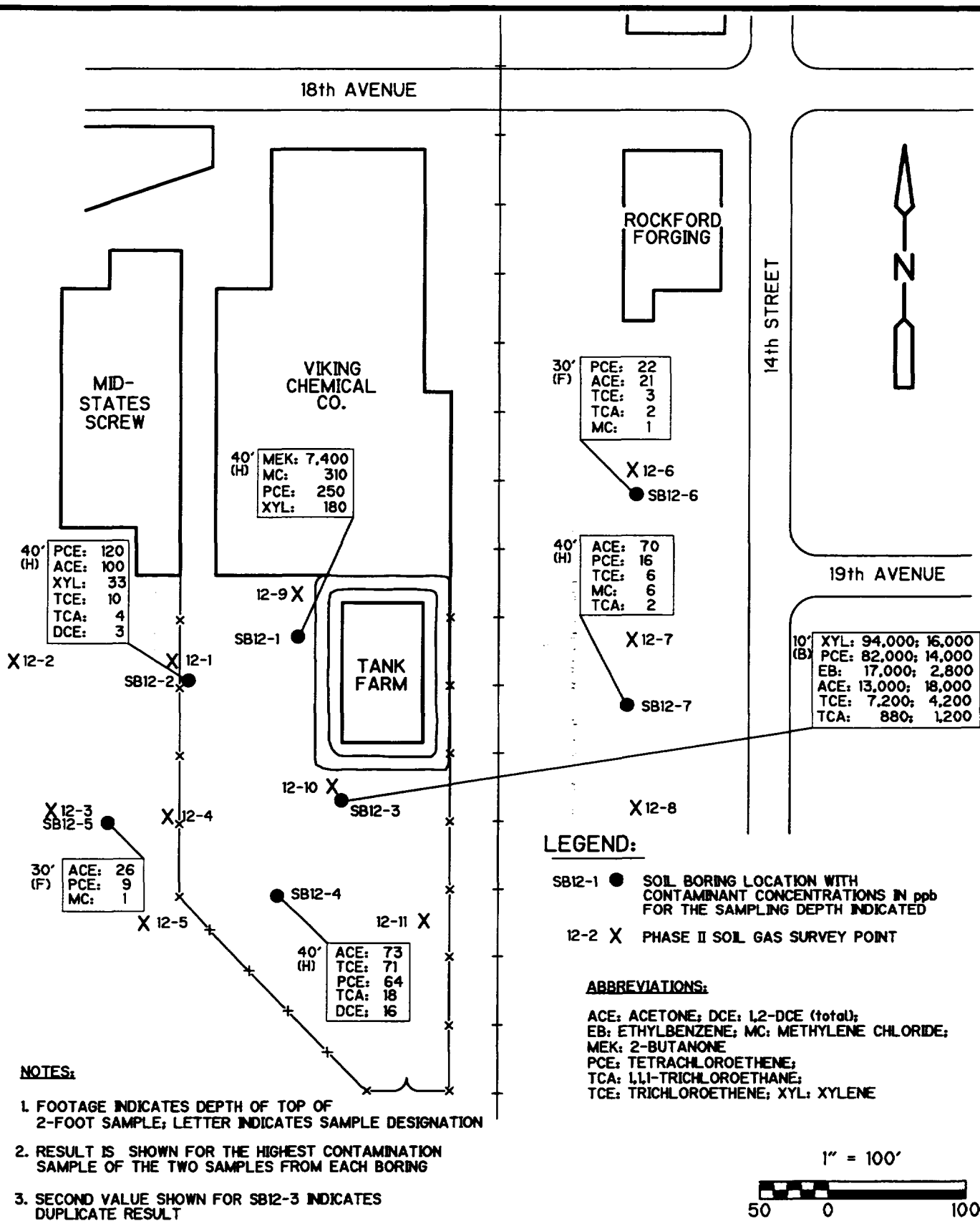
As shown in Table 4-4, in Area 11, chlorinated VOCs were detected at low concentrations in subsurface soils in non-diluted samples. Most of these detections were less than 50 ppb. The two exceptions are in SB11-7 where TCE was detected at 410 ppb and SB11-8 where methylene chloride was detected at 2,200 ppb. These detections do not result from groundwater contaminant transport from upgradient sources, because these compounds are not present at elevated concentrations upgradient from Area 11 (TCE is no more than 28 ppb in upgradient wells, and methylene chloride is undetectable). There are eight soil samples in Area 11 where detection limits were elevated by 3 or 4 orders of magnitude. It is likely that any chlorinated VOCs in these samples were masked by the high concentration of the ETX compounds. In general in the study area, the results of groundwater and subsurface soil samples from similar depths show that, in contaminant plume areas away from contaminant source areas, soil samples have contaminant concentrations of less than 100 ppb (see subsection 4.5.2). Therefore, the presence of significantly higher concentrations of methylene chloride and TCE in subsurface soils in Area 11 suggests the presence of localized sources of these contaminants in subsurface soils within Area 11. For TCE, this idea is consistent with the results of groundwater sampling in Area 11: as discussed in subsection 4.8, TCE was noted in one groundwater sample from Area 11 (IW11); however, methylene chloride was not detected in downgradient groundwater samples. It is also possible that other chlorinated VOCs are present but were not detected due to sample dilution.

TICs were reported from the VOC or semivolatile scan from most Area 11 samples, being most abundant in the high-concentration samples. These compounds were primarily unspecified alkanes, aromatics, and unknown hydrocarbons, and their total concentration was between 0.1 and 1.8 times that of the total of TCL compounds. As the primary TCL compounds (toluene, xylene, and ethylbenzene) and the TICs in Area 11 soils are all probably lighter than water, it can be concluded that any NAPL zones that may be present in Area 11 would be light NAPLs and exist at or above the water table. Because of the potential for the presence of LNAPLs in this area, additional source investigation studies should be performed in a phased manner, as previously described for Areas 4 and 7.

4.5.1.6 Area 12

Subsurface soil sampling was performed in Area 12 in order to investigate the existence and extent of VOC contamination in an area with moderate to very high concentrations of TCA, TCE, and PCE in soil gas samples. As noted above, soil gas sample SG12-4 had the highest concentrations of each of the target compounds for any soil gas samples collected in Phase I or II. Seven soil borings were drilled and sampled in Area 12. The results of subsurface soil sampling are summarized in Figure 4-25, which shows results for the sample with the highest concentration of chlorinated VOCs from each boring (one of the two samples collected from each boring).

Figure 4-25 shows that the subsurface soil VOC results in Area 12 are highly skewed, with very high concentrations limited to boring SB12-3. At this location, the 10- to 12-foot sample (SB12-



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POTENTIAL SOURCE AREA 12
SOIL GAS SAMPLING LOCATIONS AND
SUBSURFACE SOIL SAMPLING RESULTS



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3B) contained 82 ppm of PCE, and ppm-level concentrations of several other contaminants (ketones, ETX compounds). Concentrations found in SB12-3 are greater than those from other borings by a factor of about 300. The anomalously high VOC concentrations in SB12-3 may be indicative of the presence of NAPL-type contamination there, based on a similar calculation for PCE as was performed for Area 7 samples. The next-highest result for subsurface soil sampling in Area 12 was from SB12-1, located some 120 feet north of SB12-3, where the concentration of total VOCs was 8,140 ppb. At this location, however, chlorinated VOCs constitute only a small fraction of total VOCs; PCE was present at 250 ppb, while 2-butanone was reported at 7,400 ppb. The compound 2-butanone is a water-soluble ketone. As a result, NAPL-type contamination at SB12-1; the relatively high head-space results at this location probably result from elevated concentrations of 2-butanone, rather than chlorinated VOCs. This conclusion is consistent with the low soil gas sampling result from SG12-9, located within a few feet of boring SB12-1. As noted for Area 11, the head-space screening results are useful in estimating contaminant concentrations in Area 12 at depth intervals where samples were not collected (see Table 4-5). Similar to Area 11, head-space values less than 75 ppm correspond with relatively low analytical results for total VOCs (less than 10 ppm); for SB12-3B with a head-space result of 178 ppm, the analytical results for total VOCs were 226 and 71 ppm (sample and duplicate results). Using a 75-ppm threshold to indicate high-concentration VOC samples, an initial estimate of the thickness of the high-concentration zone could be approximated as 15 feet in the vicinity of SB12-3. Based only on the subsurface soil sampling results, the areal extent of the high-concentration zone is difficult to estimate; however, it appears to be less than 140 feet square, based on the lack of high-concentration hits in other borings. The soil gas sampling results are also useful in this assessment, and depict a rapid decline in concentrations of the target VOCs away from the SB12-3 location. Such a pattern in the soil gas results suggests that the high-concentration VOC zone in the subsurface does not extend far away from SB12-3, making the 140-foot-square estimate a maximum.

Based on limited knowledge of facility operations and the soil gas, headspace and soil boring data, the potential exists for DNAPL zones in Area 12. Residual NAPL in the vadose zone is suspected based on data from Phase II sampling, especially near SB12. It is also possible DNAPLs are present at depth beneath the site as some of the compounds stored at the facility (PCE, TCE) have a specific gravity greater than 1 and would sink. No specific sampling was conducted to characterize or confirm the presence of NAPLs above or below the water table. Any additional study in this area should take into account the possibility of NAPLs.

Subsurface soil sampling data from Area 12 shows an extensive area of low-concentration contamination by VOCs. Beyond boring SB12-3, the highest PCE concentration from other Area 12 borings was 250 ppb at SB12-1 (see Figure 4-25). SB12-1 appears to be located in a contaminant source area for VOCs based on elevated head-space concentrations throughout the unsaturated zone. However, as noted above, this source area at SB12-1 is dominated by non-chlorinated VOCs (mainly 2-butanone). Other elevated concentrations of chlorinated VOCs were reported from SB12-2 and 12-4. Borings SB12-2, 12-4, and 12-5 are located roughly downgradient of the zone of high contaminant concentrations at SB12-3. The results of head-space screening show that, at these downgradient locations, the saturated zone has higher VOC concentrations than the unsaturated zone (in contrast to the source areas represented by SB12-3 and SB12-1; see Figure 4-8). This fact implies that some downgradient transport of VOC contaminants in

TABLE 4-5
Summary of Subsurface Soil Sampling Results, Area 12

Sample Number	Depth, feet ¹	Organic Vapors, ppm: scan/head space ³	Analytical Results ²	
			Total VOCs, ppb	Total Chlorinated VOCs, ppb
SB12-1A	5-7	4.3/6.0	--	--
SB12-1B	10-12	38.4/30.0	--	--
SB12-1C	15-17	44.0/7.0	--	--
SB12-1D	20-22	158/73.0	130	130
SB12-1E	25-27	54.5/62.0	--	--
SB12-1F	30-32	29.3/16.0	--	--
SB12-1G	35-37 *	59.0/115	--	--
SB12-1H	40-42 *	10.4/8.0	8,140	560
SB12-2A	5-7	-/0	84	48
SB12-2B	10-12	-/0	--	--
SB12-2C	15-17	-/0	--	--
SB12-2D	20-22	-/0	--	--
SB12-2E	25-27	-/0	--	--
SB12-2F	30-32	-/1.0	--	--
SB12-2G	35-37 *	-/9.0	--	--
SB12-2H	40-42 *	-/22.0	286	141
SB12-3A	5-7	203/108	--	--
SB12-3B	10-12 *	438/178	226,080; 71,470	90,080; 19,570
SB12-3C	15-17 *	308/188	--	--
SB12-3D	20-22	15.4/24	--	--
SB12-3E	25-27	5.1/5.1	--	--
SB12-3F	30-32	17.7/12.9	--	--
SB12-3G	35-37 *	30.9/-	--	--
SB12-3H	40-42 *	34.4/-	9,080	2,000

Sample Number	Depth, feet ¹	Organic Vapors, ppm: scan/head space ³	Analytical Results ²	
			Total VOCs, ppb	Total Chlorinated VOCs, ppb
SB12-4A	5-7	0/0	--	--
SB12-4B	10-12	0/0	--	--
SB12-4C	15-17	0/0	--	--
SB12-4D	20-22	3.0/9.0	--	--
SB12-4E	25-27	17.4/10.0	--	--
SB12-4F	30-32	11.3/0	17	3
SB12-4G	35-37 *	10.0/40.4	--	--
SB12-4H	40-42 *	7.2/33.0	258	185
SB12-5A	5-7	0/0	--	--
SB12-5B	10-12	0/0	--	--
SB12-5C	15-17 *	0/5.0	--	--
SB12-5D	20-22 *	1.4/9.0	22	6
SB12-5E	25-27	0/0	--	--
SB12-5F	30-32	0/0	36	10
SB12-5G	35-37 *	5.5/68.0	--	--
SB12-5H	40-42 *	3.2/53.0	--	--
SB12-6A	5-7	0/0	--	--
SB12-6B	10-12	0/0	--	--
SB12-6C	15-17	0/0	--	--
SB12-6D	20-22	0/0.6	--	--
SB12-6E	25-27	0/0.2	--	--
SB12-6F	30-32	0/2.2	49	28
SB12-6G	35-37 *	2.2/13.3	--	--
SB12-6H	40-42 *	0.2/5.5	63	12
SB12-7A	5-7	0/0	--	--
SB12-7B	10-12	0/0	--	--
SB12-7C	15-17	[no sample]	--	--
SB12-7D	20-22	1.0/0	--	--
SB12-7E	25-27	0/0	--	--
SB12-7F	30-32	0/0	46	10
SB12-7G	35-37 *	0/0	--	--
SB12-7H	40-42 *	0/0.2	100	30

¹ - Asterisk indicates sample is saturated with water or product

² - Second value refers to result for duplicate sample

³ - Readings measured with OVM

groundwater occurs in Area 12. Upgradient borings SB12-6 and 12-7 contain low contaminant concentrations (less than 30 ppb of total chlorinated VOCs) in subsurface soils. It is unclear whether such concentrations are due to a near-surface source in this area, or due to migration in soil vapor or through dispersion in groundwater from the major source near SB12-3.

The existence of elevated concentrations of PCE, TCE, and TCA in subsurface soils near the southwestern corner of the tank farm in Area 12 was expected, based on the soil gas survey performed earlier in Phase II. However, the relative proportions of PCE, TCE, and TCA in subsurface soil samples is different from expectations. TCA was the compound present at the highest concentrations in soil gas samples, followed by TCE and then PCE. However, this order of abundance was the opposite in the subsurface soils, where PCE was at much higher concentrations than TCE or TCA, particularly in the highest concentration sample (SB12-3B). The reason for this discrepancy is unclear, but the heterogeneous nature of subsurface soils plays a part: the duplicate sample from SB12-3B (SB12-3B[D]) contained much higher proportions of TCE and TCA to PCE (about 30% and 10%, respectively) than in SB12-3B. The discrepancy is also probably a function of the higher mobility of TCA and TCE (due to higher vapor pressures) relative to PCE. Other aspects of Area 12 contamination are consistent between the soil gas and subsurface soil sampling efforts, including: 1) the existence of high concentrations of the target compounds (concentrations greater than 1,000 µg/L in soil gas, and ppm-level concentrations in subsurface soils); 2) the location and extent of the high-contaminant zone (limited to the area near SB12-3); and 3) the existence of a broad area of low-concentration samples away from this zone.

TICs were reported from the VOC or semivolatile scan in most Area 12 subsurface soils. These TICs include aromatics (trimethylbenzene and others), alkanes (unspecified), ketones, and amides at ppm-levels. TICs were most abundant in the high-concentration sample (SB12-3B and its duplicate), where they were reported at total concentrations of two to three times the concentrations of total chlorinated VOCs. The non-chlorinated compounds in Area 12 samples (including TCL compounds acetone, xylene, and the TICs) all have relatively low specific gravities of less than 0.9; as the total of these compounds is more than three times that of total chlorinated VOCs, the contaminant mixture in Area 12 likely has a specific gravity less than 1.0.

4.5.1.7 Area 14

Subsurface soil sampling in Area 14 focused on the area around the chip pit, where a previous investigation showed that underlying soils contained high concentrations (ranging from 75 to 1,020 ppm) of the target compounds and other chlorinated organics. Removal of contaminated soils at the chip pit occurred in late 1987 or 1988. In the Phase II RI, soil gas survey results yielded eight samples near the chip pit with target compound concentrations greater than 1 µg/L (peak concentration was 16 µg/L of TCA); three borings were drilled in this area (SB14-1, 14-2, and 14-3; see Figure 4-26). An additional boring (SB14-4) was drilled in the area north of the chip pit and near the railroad tracks, where disposal may have occurred.

Analytical results from subsurface soil sampling in Area 14 showed low concentrations of chlorinated VOCs, including TCA, PCE, TCE, and 1,1-DCA which were detected at concentrations of 6 ppb or less in all samples; 1,2-DCE (total) was detected in one sample (SB14-

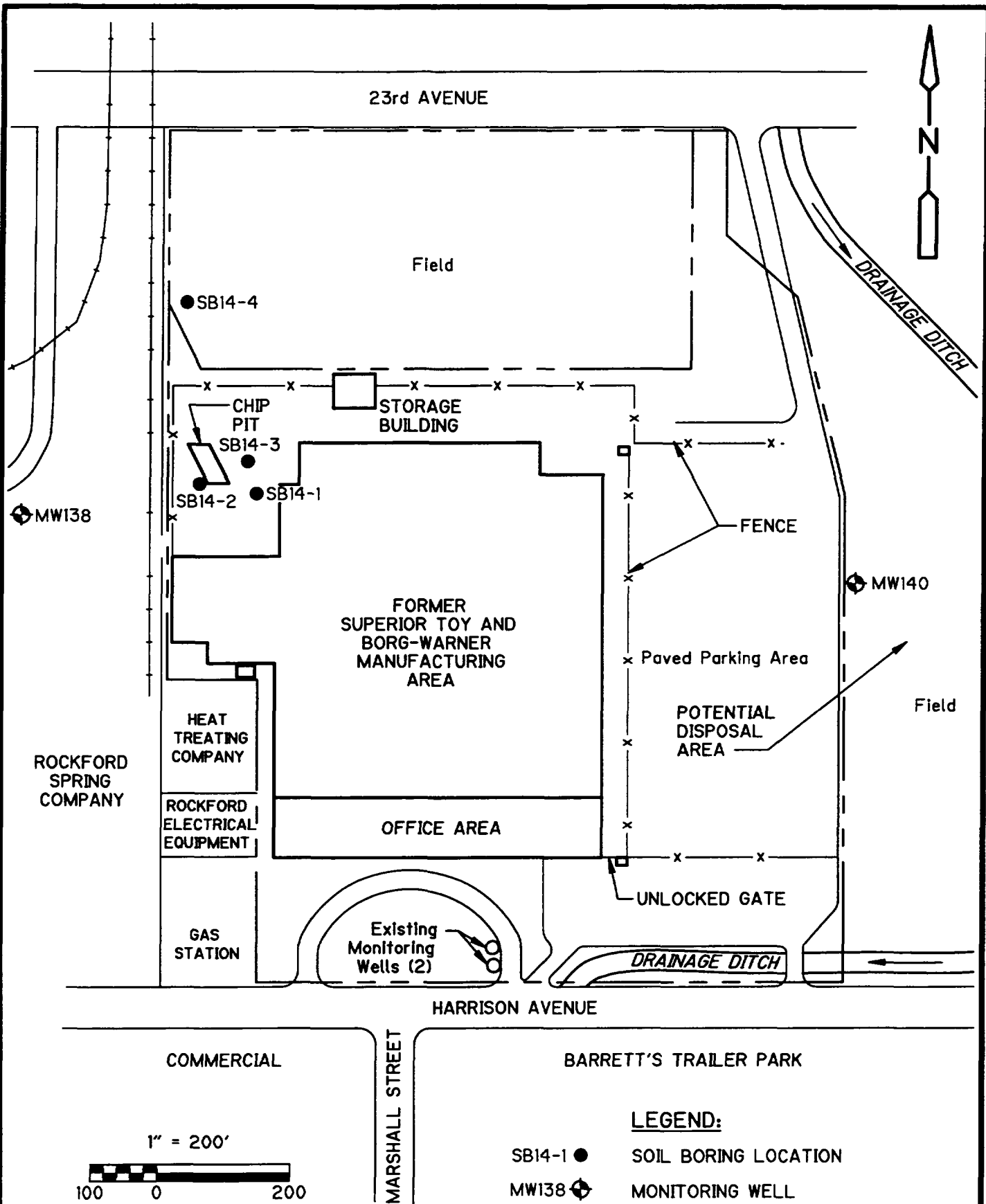
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FIG 4-26

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SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY

SUBSURFACE SOIL BORINGS POTENTIAL SOURCE AREA 14 VICINITY

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Figure No. 4-26

3A) at 48 ppb, but only one other detection (SB14-1G at 2 ppb) was noted for this compound. As a result, there is no chemical evidence of a significant ongoing VOC contaminant source at the chip pit. Sample SB14-3A, collected at five to seven feet, contained a black, oily product that showed elevated concentrations of PAH compounds (7,380 ppb), but relatively low concentrations of chlorinated VOCs or other VOCs (the peak VOC concentration was 1,2-DCE [total] at 48 ppb). Neither underlying samples (SB14-3C from 15 to 17 feet) was analyzed, nor did surrounding samples have detectable PAH concentrations, indicating limited mobility of these compounds. Slightly elevated head-space concentrations (2 to 15 ppm) were noted in deep samples (35 to 47 feet) from SB14-2. Based on the possibility that contamination at such depths and concentrations could have migrated to SB14-2 via the groundwater, samples were not analyzed from these depths.

Source Area 14 does not appear to be a significant on-going contaminant source based on the lack of detectable head-space concentrations in the unsaturated zone samples at SB14-2, combined with low head-space concentrations in the saturated zone and low VOC concentrations in analyzed samples. This conclusion is supported by the results of the soil gas survey, which showed low to undetectable concentrations of the target compounds across Area 14. However, the chip pit area may have acted as a VOC contaminant source before its removal and the removal of associated contaminated soils in late 1987 or 1988.

4.5.2 Results of Subsurface Soil Sampling Outside Potential Source Areas

Subsurface soil samples were collected from outside contaminant source areas at well nests MW114, MW119, MW126, MW130, MW133, and MW138 (three samples at each nest). Full analytical results are shown in Appendices H-4, H-5, and H-6. These samples were collected to provide information on contaminant partitioning between the groundwater and solid phases of the aquifers in the contaminant plume. Of the six wells sampled, detections were noted in samples from MW114, MW130, and MW133 (the soil samples are referred to as SB114, SB130, and SB133). The lack of detections in SB119 and SB138 are consistent with the generally low groundwater sampling results for those wells. However, the lack of detections in SB126 is not consistent with the generally high contaminant concentrations detected in wells MW126A and B; the explanation for this inconsistency may be its location in the western part of the study area, where the aquifer has low proportions of silt and clay, and adsorption is relatively less extensive (see discussion of SB114 and SB130 samples below).

Of subsurface soils from the remaining well nests, the highest results were from sample SB133H, where total VOCs were detected at 244 ppb. This sample, collected from 50 to 52 feet, was from part of the interval screened by MW133B (screened at 48 to 58 feet). MW133B was the highest-contaminated well among the wells listed above (total VOCs present at 2,967 ppb). In sample SB133H, TCA was the highest-concentration compound detected at 70 ppb, followed by PCE (58 ppb), 1,2-DCE (total) (43 ppb), TCE (38 ppb), and 1,1-DCA (12 ppb). These compounds were also the ones detected at the highest concentrations reported from the groundwater sample at MW133B.

The ratio of the concentration of a contaminant in the solid phase of an aquifer sample to its concentration in a coexisting groundwater sample is termed the distribution coefficient, K_d .

The distribution coefficient is characteristic of both the contaminant and the aquifer material; its significance is as a measure of the tendency of the contaminant to sorb onto the solid matter of the aquifer in question. The higher the distribution coefficient, the greater the tendency for the compound to sorb, and the slower its migration in groundwater due to this retardation. Distribution coefficients can be calculated for the contaminants detected in sample SB133H based on their concentrations in that formation sample, and making the assumption that the groundwater sampling results for well MW133B represent a coexisting groundwater sample. The results of these calculations for the SB133H-MW133B pair yield a range of values from 0.04 L/kg (mL/g) for 1,1-DCA to 0.36 mL/g for PCE; 1,2-DCE (total), TCA, and TCE have intermediate distribution coefficients of 0.05 mL/g, 0.06 mL/g, and 0.10 mL/g, respectively. As distribution coefficients are generally inversely related to solubility, the values calculated for the SB133H-MW133B pair follow the expected order: the lowest-solubility compound, PCE, has the highest distribution coefficient, and the highest-solubility compound, 1,1-DCA, has the lowest distribution coefficient; the other compounds have intermediate solubilities (see Table 4-10 in subsection 4.9 for solubilities). In addition, PCE will tend to be the slowest-migrating compound (the most adsorbing) of the group, while 1,1-DCA will tend to migrate the fastest. This pattern is supported by the groundwater sampling results (see subsections 4.8 and 4.9).

Shallower subsurface soil samples from SB133 (samples SB133B and SB133D) had much lower concentrations of chlorinated VOCs, which is consistent with their low concentrations (0.8 ppb total) in shallow well MW133A (screened at 25 to 35 feet). However, results for subsurface soils collected from SB114 and SB130 were relatively low despite these samples being in the contaminant plume: the maximum concentration of total VOCs was 15 ppb in these samples. The distribution coefficient for TCA calculated for the pair SB130H-MW130 yields a result of 0.003 mL/g. Calculations for the SB114C-MW37 pair (MW37, about 350 feet away, is the Phase II groundwater sample nearest to MW114 and at the proper depth; wells MW114A and B are located below the contaminant plume) yield distribution coefficients ranging from 0.02 for TCA to 0.05 for TCE. The reason for the low distribution coefficients is probably due to the second factor that influences distribution coefficients, which is the character of the aquifer material itself. As noted in Section 3, west of about 24th Street the unconsolidated aquifer consists mainly of relatively clean sand with some gravel, but very little silt or clay; east of 24th Street it contains much more silt and clay (including at MW133, where sample SB133H had a layer of sandy silt). The greater proportion of silt at MW133 probably accounts for the higher distribution coefficients at that location, because higher proportions of fine materials such as silt and clay tend to cause greater degrees of sorption of groundwater contaminants. In this way the subsurface soil data helps to provide limits on the extent of adsorption of the contaminants of concern during migration in groundwater.

4.6 Results of Residential Well Sampling

Residential well samples were collected to determine if the groundwater contamination plume had spread to houses that were not hooked up to the municipal water system during the USEPA remedial action in 1991. Residential well sampling was conducted June 8 through June 10, 1993 using the methods discussed in subsection 2.11.

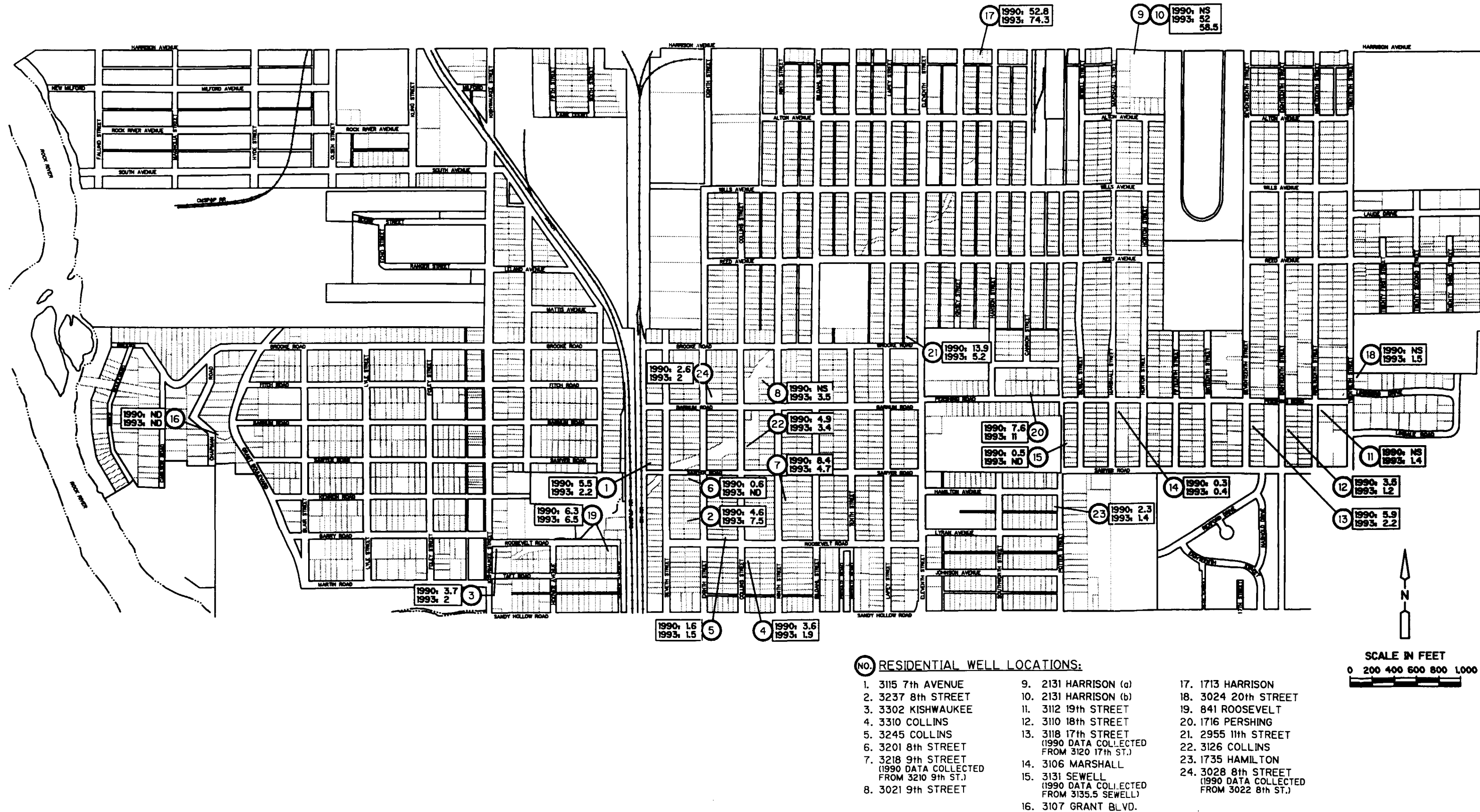
As described in subsection 2.11, residential well samples were collected at individual homes, preferably from a water source which was not connected to a water softener (such as an outside tap). Samples were analyzed using Contract Laboratory Program (CLP) Special Analytical Services (SAS) drinking water detection limit methods for volatile organic compounds. The full results for residential well samples are presented in Appendix H-7. The results were the subject of a baseline human health risk assessment (HRA), which is presented in Section 6.

Twenty-four residential wells at twenty-three different addresses were sampled in the study. The address with two wells is also the only non-single family residential well sampled in the study, belonging to Barrett's Trailer Park (2131 Harrison), and serving approximately 37 trailers and 5 homes. The sampling indicated VOC contamination with methylene chloride, 1,1-DCE, 1,1-DCA, cis-1,2-DCE, trans-1,2-DCE, chloroform, 1,2-DCA, TCA, TCE, and PCE. A list of addresses sampled are provided in Table 6-1. The frequency of detection and range of detected concentrations for the individual compounds are provided in Table 6-2.

The most prevalent contaminants detected in the residential well samples were TCA and TCE, detected in 20 out of 24 wells. PCE was detected in 15 wells, and 1,1-DCA was detected in 12 wells; the remainder of the compounds were detected in less than half of the wells sampled. Contaminants were generally detected in concentrations less than 1 ppb, although in some wells compounds were detected up to 50 ppb.

The two wells at 2131 Harrison were contaminated with all ten compounds that were detected in the residential wells sampled. Other wells contaminated with a large variety of compounds included 1713 Harrison, where seven compounds were detected, and 1726 Pershing, where six compounds were detected. The highest concentrations of compounds were detected in the wells on Harrison, and the well at 3237 Eighth Street. The highest concentrations of TCE (8 ppb), cis-1,2-DCE (10 ppb), and 1,1-DCA (15 ppb) were detected at 2131 Harrison. The highest concentrations of TCA (50 ppb) and 1,1-DCE (2 ppb) were detected at 1713 Harrison. The highest concentration of PCE (4 ppb) was detected at 3237 Eighth Street.

The two wells located at 2131 Harrison exceeded a Maximum Contaminant Level (MCL) set by the Safe Drinking Water Act. The MCL for TCE is 0.005 mg/L, and TCE was detected at 0.008 and 0.006 mg/L in these wells. No other exceedences of MCLs were detected in these residential wells or in other residential wells in the study. By design, all residential wells sampled in Phase II are located outside the main portion of the contaminant plume. Comparison of the Phase II results for residential wells with those obtained from the Operable Unit study (CDM, 1990) shows that there was little absolute variation in the results between these 1990 and 1993 sampling efforts, with one exception (see Figure 4-27 and Table 6-3 for a comparison of 1990 and 1993 results). The well at 1713 Harrison Avenue had 33 ppb of TCA in 1990, and 50 ppb in 1993. As discussed in subsection 4.8 below, this result suggests that the Area 4 plume, within which this well is located, has expanded somewhat in the intervening period. Other residential wells that were sampled are located close enough to the lateral margins of the plumes that they did not display a well-defined trend toward increasing or decreasing values during the period.



SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY
RESIDENTIAL WELL SAMPLING LOCATIONS
TOTAL VOLATILE ORGANIC COMPOUNDS DETECTED
IN 1990 AND 1993 (ppb)

Though not a primary purpose of residential well sampling, selected residential wells were used to provide additional data to characterize the nature and extent of groundwater contamination in the study area. The wells used for this purpose are located in areas where spatial coverage by monitoring wells is sparse, such as near the southern margin of the contaminant plume.

4.7 Results of Residential Air Sampling

Residential air samples were collected in order to determine if groundwater or soil contamination was affecting indoor air quality in homes located near known contaminant source areas (Areas 4 and 7). Residential air sampling was conducted near Area 7 on August 24-26, 1993 and near Area 4 on December 16-17, 1993 using the methods discussed in subsection 2.12.

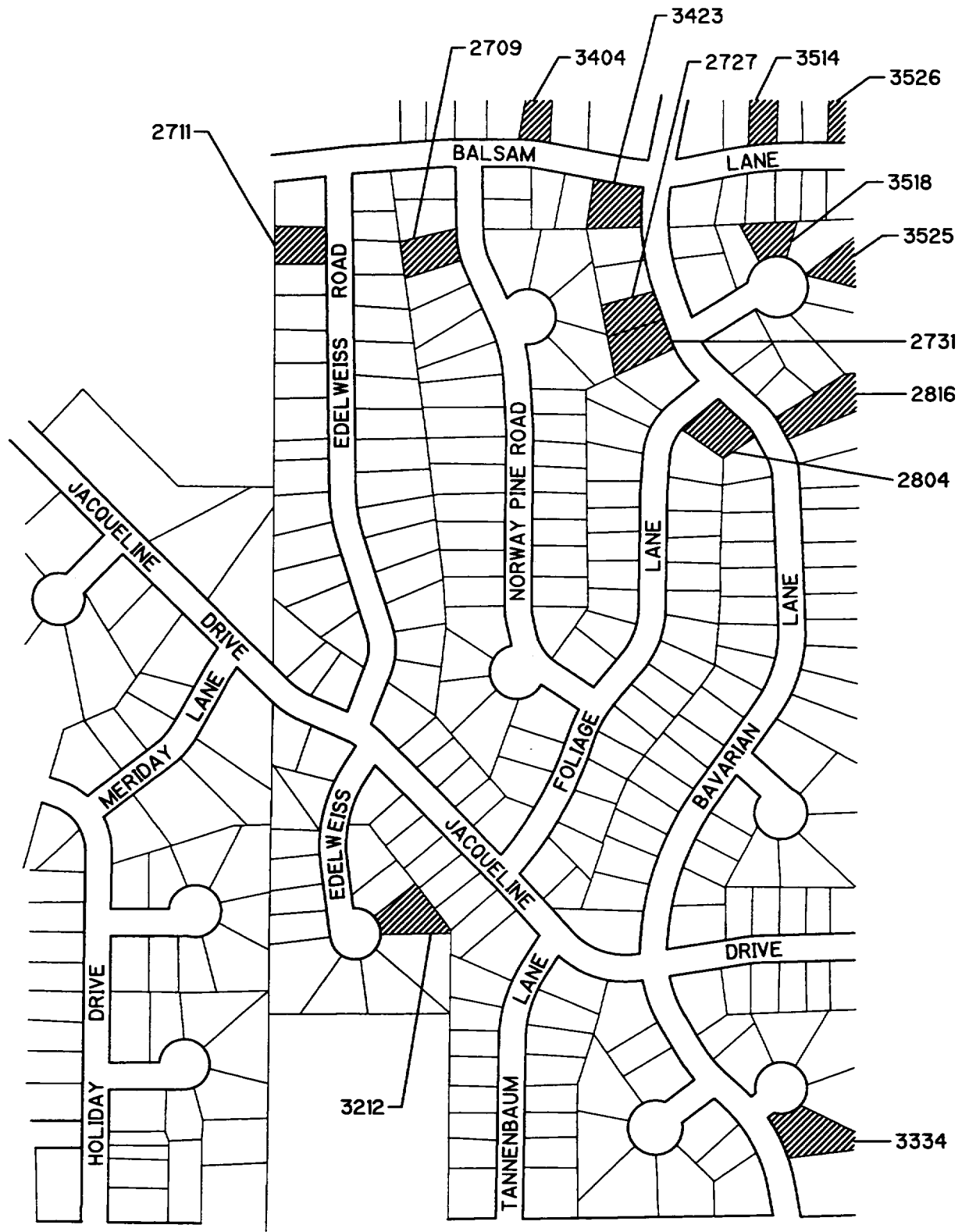
As described in subsection 2.12, residential air samples were collected by drawing an air sample into a six-liter Summa canister over a 24-hour period. Samples were analyzed for vinyl chloride, 1,1-DCE, 1,1-DCA, 1,2-DCE (total), TCA, 1,2-DCA, TCE, and PCE using EPA Method TO-14. The full analytical results for residential air samples are presented in Appendix H-8. Two samples were collected at each residence: one sample was collected indoors, in a basement location, and the other sample was collected outdoors. Both canisters were placed in the breathing zone.

Area 7

Residential air samples were collected at fourteen homes near Area 7. These locations are shown on Figure 4-28. Two of these homes were designated background locations (3212 Edelweiss Road and 3334 Bavarian Lane). Additionally, one nitrogen blank was collected. No blank contamination was detected. Nitrogen blanks were filled with 99.998% ultra-pure nitrogen from a local industrial welding supply firm. Sampling in homes near Area 7 indicated VOC contamination with TCA, TCE, and PCE.

Outdoor contamination was detected at only one home, 2731 Bavarian Lane, where 2.8 ppbv (parts per billion by volume) TCA was detected. Indoors, TCA was detected in all 14 homes, in concentrations ranging from 0.7 to 14 ppbv. TCE was detected in four homes, in concentrations ranging from 0.4 to 1.3 ppbv. PCE was detected in eight homes, in concentrations ranging from 0.2 to 7.1 ppbv.

Two homes near Area 7 (3212 Edelweiss Road and 3334 Bavarian Lane) were selected as background controls on the basis of their presumed location outside the groundwater contamination plume. Results at 3212 Edelweiss indicated 9.3 ppbv TCA and 0.6 ppbv PCE inside the home. Results at 3334 Bavarian indicate the presence of 6.8 ppbv TCA inside the home, although all results in this sample are qualified as estimated due to a holding time violation. The results for TCA in the 3334 Bavarian sample are higher than all but two of the investigative samples. The area of the two "background" locations had not been fully characterized, so groundwater contamination there is possible. Due to the prevalence of industrial facilities in the city, that have been or are users of chlorinated VOCs, it is difficult to ascertain what proportion of indoor air contamination is due to groundwater contamination, versus that which is due to a residence's proximity to industry. Also, the presence of the



SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY

AREA 7 - RESIDENTIAL AIR SAMPLING LOCATIONS



environmental engineers, scientists,
planners, & management consultants

Figure No. 4-28

compounds in these homes may be due to paints, cleaners, and hobby materials, so it is difficult to choose a background location where no activity has taken place that could contribute to elevated indoor air concentrations of these materials. A soil gas survey in this area would provide more definitive information on VOC's in the subsurface near these homes.

Area 4

Residential air samples were collected at six homes in the vicinity of Area 4. These locations are shown on Figure 4-29. A duplicate indoor sample was collected in one home. Two homes were designated as background samples (3114 16th Street and 3325 18th Street), and two nitrogen blanks were collected. The two nitrogen blanks collected during Area 4 sampling showed low-level contamination with TCA (0.18 and 0.2 ppbv) and TCE (0.51 and 0.59 ppbv). The Area 4 data, while considered useable, were qualified as follows: TCA and TCE values that are five times or less than the highest blank value were qualified with a "B". TCA and TCE values greater than five times the highest blank value were not qualified.

Background homes in the vicinity of Area 4 were selected primarily to be distant from a known surface contamination source; in addition, these homes were also located outside the presumed extent of the groundwater contamination plume. At the background residence at 3325 18th Street, the only compound detected was PCE, at 2.6 ppbv inside the home. While this is the highest PCE level detected during this round of sampling, the lack of detections of other compounds means that the total detected concentration was much less than the samples nearer to Area 4. The second background residence (3114 16th Street) had no reported detections. The data will still be used, despite the lack of clean background samples. It should be noted that the background samples were nearly clean, and show a clear contrast with the samples collected from nearer to the known source area (Area 4).

Outdoor air contamination was not detected at any of the six residences. Indoors, TCA was detected at three of the six residences, in concentrations ranging from 4.9 to 130 ppbv. TCE was detected in three residences at concentrations ranging from 0.16 to 0.88 ppbv. PCE was detected at two residences, at 0.31 and 2.6 ppbv. The compounds 1,1-DCE and 1,1-DCA were detected at one residence, 2114 Alton Avenue, at 9.3 and 1.9 ppbv, respectively.

The highest contaminant concentrations were reported from the three homes nearest to the known source at Area 4, with 2114 Alton Avenue, 2641 Marshall Street, and 2645 Marshall Street containing 130, 32, and 5.1 (4.9 in the duplicate) ppbv of TCA, respectively. These were also the three homes with detectable TCE. These results are consistent with the results of soil gas, subsurface soil, and groundwater sampling in and near Area 4, which show high TCA concentrations and low TCE concentrations in samples collected near the Swebco Manufacturing parking lot in Area 4 (see subsections 4.2, 4.5, and 4.8).

Comparison With Other Sampling Efforts

The residential air sampling results are generally consistent with the soil gas, subsurface soil, and groundwater sampling results from Areas 4 and 7. At homes near Area 7, the most abundant contaminant in residential air was TCA, followed by PCE and TCE. These results are broadly

AREA 4 BOUNDARY

2630

2641

2645

2114

3114

3325



SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY

RESIDENTIAL AIR SAMPLING LOCATIONS
AREA 4 VICINITY

CDM

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Figure No. 4-29

concordant with subsurface soil sampling results (see subsection 4.5) in Area 7, which show a near-surface contaminant source of TCA with lesser amounts of PCE and TCE; other chlorinated compounds are generally present at much lower concentrations. The Area 7 contaminant source appears to be located as close as about 250 feet east of the easternmost home sampled, 3526 Balsam Lane (see subsection 4.5). In contrast to subsurface soils, groundwater samples collected from downgradient of Area 7 contained 1,2-DCE(total), 1,1-DCA, and 1,1-DCE as well as TCA, TCE, and PCE; 1,2-DCA and vinyl chloride were detected in groundwater, but at much lower concentrations. As TCA, TCE, and PCE were the only compounds detected in the residential air samples, the air medium may be most influenced by the volatilization of contaminants from the subsurface soils from Area 7, rather than by volatilization from the groundwater.

In Area 4, residential air sampling showed considerably higher concentrations of TCA, while PCE and TCE were not appreciably different than in Area 7. This pattern is consistent with the results of soil gas sampling (subsection 4.2), subsurface soil sampling (subsection 4.5), and groundwater sampling (subsection 4.8) at and downgradient from Area 4, which showed high concentrations of TCA and much lower (though still elevated) concentrations of PCE and TCE. The results of these other sampling efforts suggest the presence of a TCA contaminant source beneath the northern portion of the parking lot at Swebco Manufacturing. This source area is located as near as about 150 feet from some of the Area 4 residential air sampling locations.

In comparison to Area 7, the samples collected from near Area 4 displayed significantly higher contaminant levels. The reason for this is probably threefold: 1) the Area 4 homes with the high values are located nearer to the known contaminant source area (about 150 feet, as opposed to greater than 250 feet for all homes near Area 7); 2) subsurface soils in Area 4 are sandy and are thus more permeable than the silty sands of Area 7; and 3) the parking lot overlying the contaminant source in Area 4 acts as an impermeable surface that limits the upward escape of vapors - instead, vapors volatilizing from that source tend to migrate upward to the lower surface of the parking lot and then move laterally to unpaved areas, where they can more easily escape to the atmosphere; the Area 4 homes with elevated concentrations are located less than 50 feet from the continuously paved area that overlies the Area 4 contaminant source. The effect of the pavement was also noted in subsection 4.2, based on its apparent effect on soil gas results.

Comparison to Expected Levels

Typical outdoor air concentrations were obtained from Sweet and Vermette (1992). The study presented outdoor air concentrations and sources for 13 VOCs from the urban locations of southeast Chicago and East St. Louis as well as results from a rural site for comparison. The study employed the same Summa canister sampling technique.

Indoor air concentrations were obtained from four papers: "Concentrations of 20 Volatile Organic Compounds in the Air and Drinking Water of 350 Residents of New Jersey Compared With Concentrations in their Exhaled Breath" (Wallace, 1986), where ambient air was collected onto Tenax tubes, "Distribution of Volatile Organic Chemicals in Outdoor and Indoor Air (Shah and Singh, 1988), which presented a compiled database, "Assessment of Population Exposure and Carcinogenic Risk Posed by Volatile Organic Compounds in Indoor Air" (Stolwijk, 1989), presenting an international VOC database, and "Indoor Air Quality Data Base for Organic

Compounds (EPA, 1992) which presented a range of detected concentrations for each chemical. A summary of these outdoor and indoor air concentrations is presented in Table 4-6. Detected concentrations of PCE in both Areas 4 and 7 tended to be below indoor air concentrations as compared to results from the above-mentioned references that range from 0.23 ppb to 2.4 ppb PCE. Exceptions were samples collected at 2727 Bavarian Lane in Area 7 (7.1 ppbv PCE) and at 3325 18th Street (a designated background sample for Area 4 at 2.6 ppbv PCE).

TCA was detected inside every Area 7 residence, outside one Area 7 home, and inside three Area 4 homes. Outdoor urban background concentrations reported by Sweet and Vermette (1992) are 0.56 and 0.66 ppb. TCA detected outside Area 4 homes was below these levels; TCA detected outside 2731 Bavarian Lane in Area 7 was 2.8 ppb TCA. The four indoor air data sources presented a range of TCA concentrations from 0.47 to 8.1 ppb. Four samples exceeded this range, two in Area 7 and two in Area 4. In Area 7, TCA was detected at 9.3 ppbv in 3212 Edelweiss Road (a background sample) and at 14 ppbv in 2816 Bavarian Lane. In Area 4, TCA was detected at 32 ppbv in 2641 Marshall Street, and at 130 ppbv in 2114 Alton Avenue.

Indoor air concentrations of TCE have been reported in the above studies to range from 0.13 to 3.3 ppb. All detected TCE concentrations are below these levels. There is no indoor air data for 1,1-DCA, which was detected at 2114 Alton Avenue at 1.9 ppbv. However, 1,1-DCE, which was detected at the same residence at 9.3 ppbv, exceeds USEPA database information, which presented a range of 2.7 to 3.3 ppb.

Toxicity Assessment

Table 4-7 presents proposed risk-based air guidelines for chemicals detected in residences from the August and December sampling rounds. These guidelines are based on chronic noncarcinogenic health endpoints due to limited evidence of carcinogenicity. Ideally these concentrations would be represented by chronic inhalation reference concentrations (RfCs). In cases where inhalation RfCs were unavailable, concentrations were derived from an oral reference dose (RfD). To derive an air guideline concentration from an oral RfD, the following equation was used:

$$[c] = \text{RfD} \times \text{BW} / \text{IR} \times \text{EF}$$

where:

[c] - environmental concentration
RfD - USEPA reference dose
BW - body weight
IR - inhalation rate
EF - exposure factor

To obtain conservative air guideline concentrations, the body weight (20 kg) and inhalation rate (8.3 ug/m³) of a 5 year old child was assumed for the exposure scenario. It also assumes the exposure is intermittent and occurs in a finished family room or recreational room in the

TABLE 4-6
OUTDOOR AND INDOOR AIR CONCENTRATIONS FROM VARIOUS AIR QUALITY STUDIES
FOR DETECTED VOLATILE ORGANIC CHEMICALS

	Illinois Outdoor Air			Indoor Air Studies			
Sampling Method	SUMMA Canister	SUMMA Canister	SUMMA Canister	Tenax with Pump	Various Methods	Sorbent Methods	Various Methods
Volatile Organic Compound	Chicago Outdoor Air Conc. (1) (ppb)	East St. Louis Outdoor Air Conc. (1) (ppb)	Rural Site Outdoor Air Conc. (1) (ppb)	New Jersey Indoor Air Conc. (2) (ppb)	CA, NJ Indoor Air Conc. (3) (ppb)	4 Countries Indoor Air Conc. (4) (ppb)	EPA Indoor Air Conc. (5) (ppb)
1,1-Dichloroethane	NA	NA	NA	NA	NA	NA	NA
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	2.7 - 3.3
Tetrachloroethene	0.24	0.19	0.05	0.86	0.74	0.67	0.23 - 2.4
1,1,1-Trichloroethane	0.56	0.66	0.19	2.9	1.8	0.84	0.47 - 8.1
Trichloroethene	0.17	0.36	0.1	0.39	0.13	0.85	0.15 - 3.3

Notes:

(1): Sweet and Vermette, 1992.

(2): Wallace et. al., 1985.

(3): Shoh and Singh, 1988.

(4): Stolwijk, 1990.

(5): EPA, 1992.

NA: Not Available

TABLE 4-7
HEALTH RISK-BASED AIR GUIDELINES CONCENTRATIONS

Chemical	Risk - Based Air Concentration (ppb)	Study Type	Species	Critical Effects	Common Sources in Indoor Air
1,1-Dichloroethane	25 (1)	13 week, inhalation	rat	none observed	Not Available
1,1-Dichloroethene	20 (2)	2 year, drinking water	rat	hepatic lesions	Not Available
Tetrachloroethene	15 (2)	6 week, gavage	mouse	hepatic toxicity	Dry cleaning, adhesives, foam insulation, inks
1,1,1-Trichloroethane	150 (3)	occupational, inhalation	human	systemic effects	Dry cleaning, cleaning fluid
Trichloroethene	10 (4)				Adhesives, foam insulation, inks, photo films

Notes:

(1): HEAST, 1993 RfC converted to ppb units

(2): IRIS, 1993 value derived from RfD

(3): ATSDR, 1990 value derived from NOAEL from Kramer et. al.

(4): Risk Assessment Issue Paper for: Provisional RfD for Trichloroethylene (CASRN 79-01) derived from provisional RfD

basement where the contaminants were monitored. The exposure factor was derived by calculating the approximate number of hours spent in the family room in a year (2840 hours) divided by the total number of hours in a year (8760 hours) resulting in a factor of 0.32. This value was multiplied by 0.75 to account for 75% absorption through the lungs of total inhaled air based on trichloroethene (Santodonato, et al., 1985) resulting in an exposure factor of 0.25.

The risk-based air concentration of 25 ppb for 1,1-dichloroethane was represented by a chronic RfC of 100 ug/m³ converted to ppb units. The RfC value was obtained from the 1993 USEPA Health Effects Assessment Summary Tables (HEAST).

The risk-based air concentration of 20 ppb for 1,1-dichloroethene is 20 ppb derived from an oral RfD of 0.009 mg/kg/day obtained from EPA's Integrated Risk Information System (IRIS)(USEPA, 1993). The RfD was based on a 2 year rat drinking water study. To obtain the risk-based concentration the RfD was multiplied by body weight (20 kg) and divided by inhalation rate (8.3 ug/m³) and an exposure factor (0.25). The resulting concentration of 86 ug/m³ was converted to ppb units.

The risk-based air concentration of 15 ppb for tetrachloroethene was derived from an oral RfD of 0.01 mg/kg/day obtained from IRIS (USEPA, 1993). The RfD was based on a six-week mouse gavage study. To obtain the risk-based air concentration the RfD was multiplied by body weight (20 kg) and divided by inhalation rate (8.3 m³) and an exposure factor (0.25). The resulting concentration of 96 ug/m³ was converted to ppb units.

The risk-based air concentration of 1,1,1-trichloroethane is based on the most conservative NOAEL of 150 ppm from the ASTDR. RfC and RfD values were removed from the HEAST database due to uncertainty regarding critical effect and the appropriate study. The HEAST RfC that was removed was 1000 ug/m³ or 180 ppb. The more conservative NOAEL of 150 ppm from the Kramer et al. occupational study was divided by an uncertainty factor of 1000 resulting in the air concentration of 150 ppb. The total uncertainty factor was based on the individual factor combination of 10 for interspecies variation, 10 for a subchronic study and 10 to protect sensitive individuals.

The risk-based air concentration of 10 ppb for trichloroethene was derived from a provisional RfD based on the principal study by Tucker et al. (Risk Assessment Issue Paper for: Provisional Oral RfD for trichloroethylene (CASRN 79-01)). The provisional RfD of 6 ug/kg/day was multiplied by a body weight of 20 kg and divided by an inhalation rate of 8.3 m³ and an exposure factor of 0.25.

Risk Characterization

To assess health risks to Southeast Rockford residents associated with chronic exposure to volatile organic chemicals, air concentrations from residents homes are compared to the air guidelines presented in the toxicity assessment.

The most frequently detected chemical was 1,1,1-trichloroethane which was detected in all 18 of the homes sampled. All of the detected residential concentrations were below the derived guideline of 150 ppb for TCA. The highest detected concentration was 130 ppb from 2114 Alton

Street. The remaining concentrations were substantially below the guideline with concentrations ranging from 0.36 ppb to 32 ppb.

PCE was detected in eight of the 18 homes sampled. All eight of the detected concentrations (ranging from 0.2 ppb to 2.6 ppb) were well below the derived guideline concentration of 15 ppb.

TCE was detected in seven out of 18 homes. All of the detected concentrations (ranging from 0.16 ppb to 1.3 ppb) were well below the derived guideline concentration of 10 ppb.

The chemicals 1,1-DCA and 1,1-DCE were only detected at the 2114 Alton Street residence which also had the highest concentration of TCA (130 ppb). The 1,1-DCA concentration of 1.9 ppb was below the derived guideline concentration of 25 ppb and the 1,1-DCE concentration of 9.3 ppb was below the derived guideline concentration of 20 ppb.

All of the chemicals detected in residential homes were below health-based air guidelines. The three primary chemicals detected - PCE, TCA, and TCE - are three of the most commonly detected volatile organic compounds detected in indoor air (EPA, 1992). Common sources of these chemicals are dry cleaning, adhesives, foam insulation and inks (see Toxicity Table). Although these same chemicals have been detected in the groundwater, at this time, there is insufficient residential air data to draw a correlation between concentrations in the groundwater and concentrations in the indoor air. Residential air data may be further addressed in risk assessments for Area 4 and Area 7 source studies.

4.8 Nature and Extent of Groundwater Contamination

Phase I of the Remedial Investigation (RI) established that an extensive area of groundwater contamination exists in the unconsolidated aquifer and the Galena-Platteville (dolomite) aquifer in southeast Rockford. Several contaminant plumes were identified in this area that extends from the residential neighborhood where contamination resulted in the removal and remedial actions by USEPA (consisting of extending water mains and hookups to residences affected by the plume; see section 1) to east of Alpine Road located approximately two miles upgradient (east) of the residential area. Phase II work comprised a source investigation and a groundwater investigation. The source investigation was designed to evaluate whether identified potential source areas are related to the observed groundwater contamination; the groundwater investigation was designed to more fully evaluate the nature and extent of groundwater contamination as well as the properties of the aquifers of concern (unconsolidated and Galena-Platteville), and to provide data that could be used in the feasibility study. Because these purposes are to some extent overlapping and for the sake of simplicity, results from groundwater sampling of wells installed for both the source investigation and the groundwater investigation will be discussed together.

As was shown by the results of the Phase I RI, the contaminants of concern in the groundwater in the study area are VOCs. Extractable semivolatiles, pesticides, PCBs, and inorganic constituents were either not detected in Phase I or were not present at concentrations above background across most of the study area, and only localized detections of certain constituents of

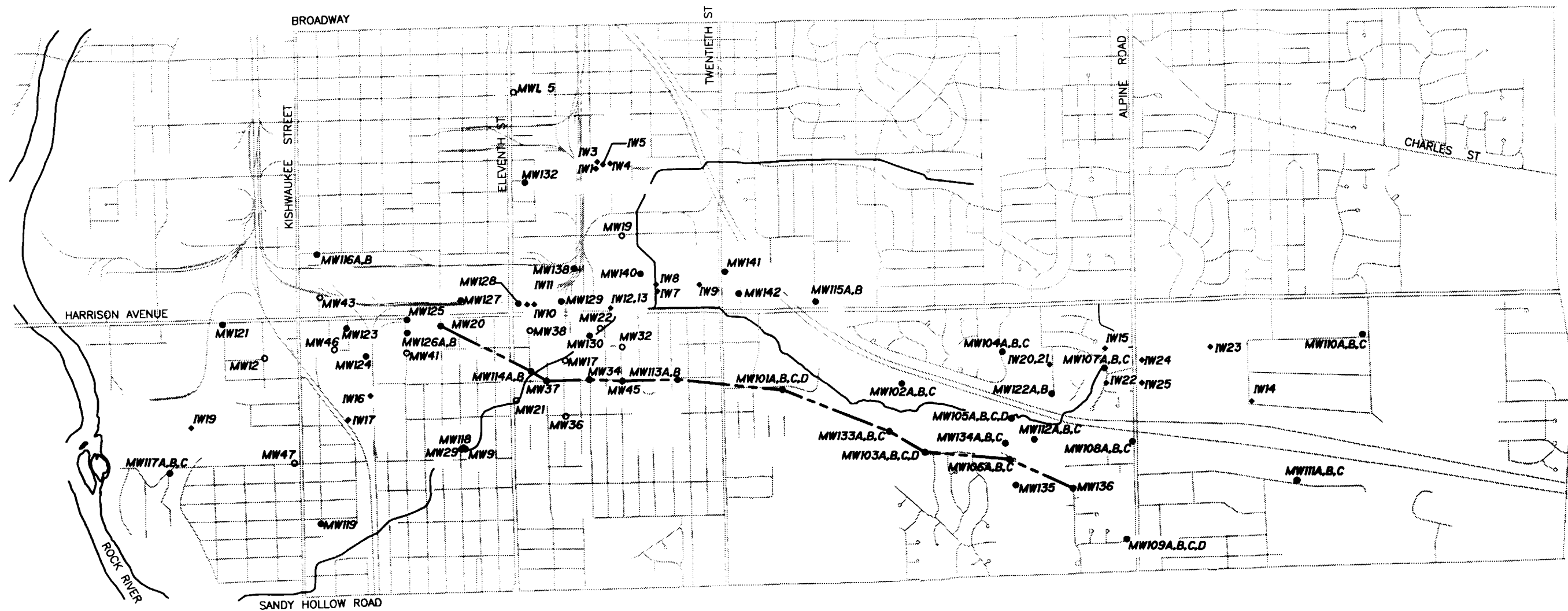
these were noted. As a result, in Phase II the existing wells were sampled for VOCs only, while newly installed (Phase II) wells were sampled for the full suite of organic constituents in the Target Compound List and inorganics in the Target Analyte List. Details of groundwatersampling methods are presented in subsection 2.7; the wells sampled in Phase II are presented in Figure 4-30. A total of 120 wells were sampled for VOCs during Phase II. The ranges and frequencies of detection for all organic compounds detected in Phase II groundwater samples are presented in Table 4-8 for both the unconsolidated and bedrock (including the dolomite and sandstone; see following paragraph) aquifers. The full results for VOCs in groundwater samples are given in Appendix H-9. Results for VOC sampling from both Phases I and II were also used in groundwater modeling (see Section 5).

As shown in Section 3, the unconsolidated and Galena-Platteville aquifers are generally hydraulically connected across the study area. As a result, there is no barrier to the downward migration of contaminants from the unconsolidated aquifer into the Galena-Platteville throughout most of the study area. However, there are thick discontinuous silt and clay deposits in the study area which would locally restrict the downward migration of contaminants (see Section 3). In addition to bedrock wells in the Galena-Platteville Group, two of the wells sampled in Phase II are screened in the St. Peter Sandstone (MW112C and MW114B). As discussed in Section 3, the St. Peter is near the top of the bedrock at MW114 and is apparently hydraulically connected with the unconsolidated aquifer at that location. At MW112, the St. Peter is hydraulically isolated from the overlying Galena-Platteville Group and the unconsolidated deposits by an intervening aquitard, the Glenwood Formation. This formation likely acts to restrict the downward migration of contaminants into the St. Peter Sandstone at this location, which is consistent with the fact that only one organic constituent was detected at a very low concentration (1,1-DCE at 0.8 ppb) from MW112C. Apart from MW112C, the other monitoring wells sampled in Phase II are part of the same interconnected shallow aquifer system. As a result, the sample results from wells in both aquifers will be discussed together in the remainder of this subsection.

As noted above, the unconsolidated and Galena-Platteville aquifers are hydraulically connected throughout the study area. As a result, maps of contaminant concentrations in groundwater show results for all wells regardless of aquifer screened. Contours are based on the peak contaminant concentration at a given well nest, whether it occurs in the unconsolidated or dolomite aquifer. Vertical patterns of contamination are discussed in the text and are illustrated in cross-sections. While the contours are based primarily on contaminant concentrations, contours were also drawn to be generally consistent with groundwater flow directions. This technique was used especially in areas of sparse sample coverage.

TCA

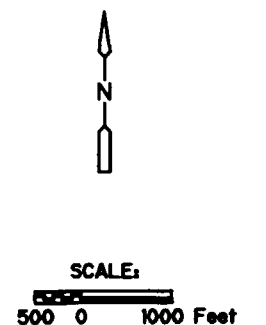
TCA was the most abundant VOC detected in wells sampled during Phase II, both in terms of frequency of abundance, and in terms of overall abundance. TCA is a common degreasing solvent that is also used in cleaning precision instruments, in pesticides, and in textile processing. Though several other compounds were present at higher concentrations in some samples, in most samples these compounds were considerably less abundant than TCA. TCA was detected in 65 of the 88 (74%) unconsolidated aquifer wells, and in 23 of the 32 (72%) of the



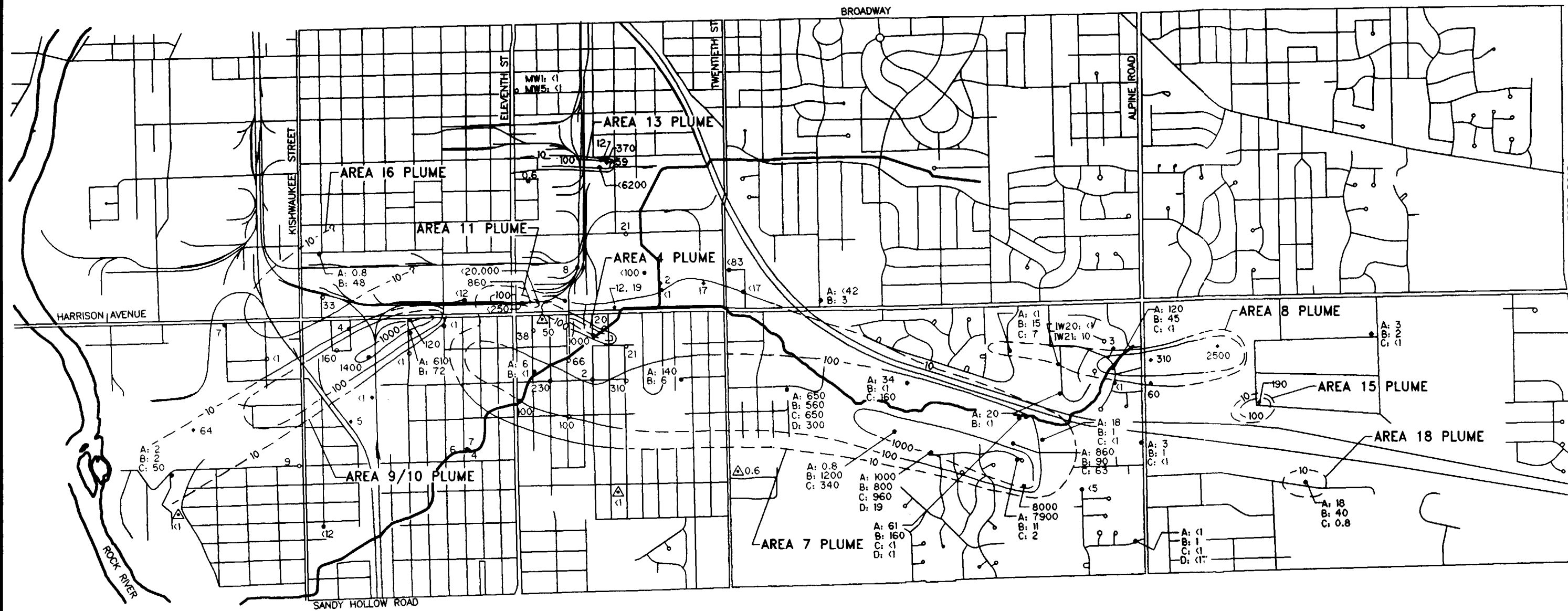
NOTE:
AREA 7 CONTAMINANT PLUME CROSS SECTION
REFER TO FIGURE 4-32

LEGEND:

- MW12 ISWS MONITORING WELL
- MW101 CDM/IEPA MONITORING WELL OR WELL NEST; LETTER SUFFIX INDICATES SPECIFIC WELL OF A WELL NEST
- ◆ IW14 INDUSTRIAL MONITORING WELL OR SUPPLY WELL



SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY MONITORING WELLS SAMPLED IN PHASE II RI



NOTES:

1. TO REDUCE CLUTTER ON THE MAP, FULL WELL NAMES ARE NOT INCLUDED; REFER TO FIGURE 3-3 FOR WELL NAMES
2. CONTOURS ARE BASED ON MAXIMUM TCA CONCENTRATIONS AT A GIVEN WELL NEST.
3. MW114A AND B WERE NOT USED IN CONTOURING, BECAUSE THEY ARE SCREENED BELOW THE CONTAMINATED INTERVAL.

LEGEND:

- 21 ISWS MONITORING WELL WITH TCA CONCENTRATION, ppb
- A: 140 CDM/IEPA MONITORING WELL NEST OR WELL WITH TCA CONCENTRATION, ppb; LETTER INDICATES SPECIFIC WELL OF A WELL NEST
- 60 INDUSTRIAL SUPPLY WELL OR MONITORING WELL WITH TCA CONCENTRATION, ppb
- △ <1 SELECTED RESIDENTIAL WELL SAMPLING LOCATION (RESIDENTIAL WELL LOCATIONS, ADDRESSES AND COMPLETE RESULTS ARE GIVEN IN SECTION 6)
- 100- CONTOUR OF MAXIMUM TCA CONCENTRATION AT WELL NEST OR WELL LOCATION; DASHED WHERE INFERRED

SCALE:
500 0 1000 Feet

SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY

TCA IN GROUNDWATER
IN PHASE II SAMPLES

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contamination, such as the subsurface soils in Area 7. Downgradient from these wells, the TCA plume becomes thicker and the vertical center of mass of TCA generally moves downward. These patterns are illustrated in Figure 4-32, which shows concentrations of total chlorinated VOCs along the length of the Area 7 plume. Although this figure shows only total chlorinated VOCs, the patterns are very similar for TCA, because it is the most abundant of the chlorinated VOCs, and it constitutes a generally constant proportion of total VOCs. As shown in Figure 4-32, the bottom portion of the TCA plume migrates into the Galena-Platteville (dolomite) aquifer in the area MW106. This migration results in large chlorinated VOC (and TCA) concentrations in dolomite wells MW103B and C, MW133C, MW102C, and MW101B, C, and D; at well nests MW103, MW133, and MW101 the concentrations in the dolomite (340 to 1,200 ppb) are roughly similar to those observed in the unconsolidated aquifer (at MW103A, MW133B, and MW101A). At MW102, greater concentrations are present in MW102C in the dolomite aquifer. Although TCA is present in the unconsolidated aquifer at MW102A, the semi-confining conditions for this well would likely prevent downward migration of contamination to underlying portions of the aquifer. MW102A is screened in the uppermost water-bearing sand. This sand unit is bounded above and below by clay units, which probably accounts for the 14-foot head difference between MW102A and MW102B. Downward migration of TCA at other locations is fostered by the hydraulic connection between the unconsolidated and dolomite aquifers (see subsection 3.2.1), combined with downward hydraulic gradients, such as those observed at well nests MW106 and MW134, and by fractures in the dolomite.

At well nests MW103, MW133, and MW101, the center of mass of the TCA plume is probably a short distance below the unconsolidated-dolomite contact. At MW113, however, TCA concentrations are significantly greater near the contact (at MW113A) than at a greater depth in the dolomite (at MW113B). Two possible reasons for this are: 1) the horizontal center of the TCA plume in the dolomite is some distance north or south of this location; or 2) MW113 is near the deeper portion of the downgradient margin of the contaminant plume in the dolomite aquifer. There are no other nearby dolomite wells to evaluate which alternative is correct.

It is likely that the Area 7 TCA plume in the shallow bedrock (Galena-Platteville Group) does not continue far to the west of MW113, because the Galena-Platteville Group pinches out approximately 2,000 feet west of MW113 (see Figures 3-4 and 4-32). Just west of where the Galena-Platteville was eroded (such as at MW114), the Glenwood Formation is the uppermost bedrock unit (see Figure 4-32). Any contaminants still present in the Galena-Platteville just east of where it pinches out would tend to migrate westward above the Glenwood, being forced out into the unconsolidated aquifer at the point where the Galena-Platteville pinches out. A short distance to the west of MW114, the Glenwood Formation is absent, and the St. Peter Sandstone is the uppermost bedrock unit. Deeper bedrock units do not appear to be affected by contamination at MW114B, which is screened in the St. Peter just below the Glenwood Formation, and near the area where the St. Peter is the uppermost bedrock unit. Furthermore, the bulk of the plume appears to be significantly above the bedrock in this area: low contaminant concentrations (19 ppb total VOCs) were observed in the Phase II sample from MW114A, screened at a depth of 85 to 95 feet (bedrock is at 192 feet), while previous ISWS samples from shallower wells MW16 (screened at 48 feet) and MW31 (62 feet) at the same location showed much higher VOC concentrations (greater than 300 ppb total VOCs).

Table 4 - 8: Groundwater Organic Compounds - Range and Frequency of Detection

Constituent	MCL, ppb	Unconsolidated Aquifer			Bedrock Aquifer		
		Range of Phase II Samples With Detections, ppb	Proportion of Phase II Samples With Detections	Proportion of Samples at or Exceeding MCL	Range of Phase II Samples With Detections, ppb	Proportion of Phase II Samples With Detections	Proportion of Samples at or Exceeding MCL
<i>Volatile Organics</i>							
Vinyl Chloride	2	1 - 75	8 / 88 (9%)	7 / 88 (8%)	1 - 1	2 / 32 (6%)	0 / 32 (0%)
Chloroethane	--	4 - 500	7 / 88 (8%)	N/A	2 - 2	1 / 32 (3%)	N/A
Methylene Chloride	5	2 - 2700	4 / 88 (5%)	3 / 88 (3%)	2 - 390	3 / 32 (9%)	2 / 32 (6%)
Acetone	--	1500 - 1800	2 / 88 (2%)	N/A	17 - 17	1 / 32 (3%)	N/A
1,1-Dichloroethene	7	0.6 - 410	41 / 88 (47%)	24 / 88 (27%)	0.5 - 440	21 / 32 (66%)	11 / 32 (34%)
1,1-Dichloroethane	--	1 - 2100	47 / 88 (53%)	N/A	0.7 - 660	21 / 32 (66%)	N/A
cis-1,2-Dichloroethene	70	0.3 - 5900	40 / 69 (58%)	6 / 69 (9%)	4 - 210	11 / 27 (41%)	3 / 27 (11%)
trans-1,2-Dichloroethene	100	1 - 8	5 / 69 (7%)	0 / 69 (0%)	1 - 1	1 / 27 (4%)	0 / 27 (0%)
1,2-Dichloroethene (total)	--	4 - 2800	13 / 19 (68%)	N/A	120 - 390	5 / 5 (100%)	N/A
Chloroform	--	0.6 - 14	8 / 88 (9%)	N/A	5 - 28	3 / 32 (9%)	N/A
1,2-Dichloroethane	5	0.8 - 28	10 / 88 (11%)	6 / 88 (7%)	0.9 - 4	3 / 32 (9%)	0 / 32 (0%)
2-Butanone	--	8 - 9800	8 / 88 (7%)	N/A	11 - 68	3 / 32 (9%)	N/A
Bromochloromethane	--	5 - 5	1 / 88 (1%)	N/A	0 - 0	0 / 32 (0%)	N/A
1,1,1-Trichloroethane	200	0.6 - 8000	65 / 88 (74%)	13 / 88 (15%)	0.8 - 2500	23 / 32 (72%)	8 / 32 (25%)
1,2-Dichloropropane	5	7 - 7	1 / 88 (1%)	1 / 88 (1%)	0 - 0	0 / 32 (0%)	0 / 32 (0%)
Trichloroethene	5	0.5 - 1500	62 / 88 (70%)	40 / 88 (45%)	0.7 - 430	17 / 32 (53%)	14 / 32 (44%)
1,1,2-Trichloroethane	5	4 - 60	2 / 88 (2%)	1 / 88 (1%)	0 - 0	0 / 32 (0%)	0 / 32 (0%)
Benzene	5	2 - 1000	7 / 88 (8%)	4 / 88 (5%)	45 - 45	1 / 32 (3%)	1 / 32 (3%)
4-Methyl-2-Pentanone	--	7 - 18000	4 / 88 (5%)	N/A	16 - 16	1 / 32 (3%)	N/A
2-Hexanone	--	15 - 15	1 / 88 (1%)	N/A	0 - 0	0 / 32 (0%)	N/A
Tetrachloroethene	5	0.4 - 1200	40 / 88 (45%)	19 / 88 (22%)	0.6 - 310	14 / 32 (44%)	10 / 32 (31%)
Toluene	1000	0.3 - 310000	23 / 88 (26%)	7 / 88 (8%)	5 - 2200	5 / 32 (16%)	1 / 32 (3%)
Ethylbenzene	700	1 - 4200	13 / 88 (15%)	4 / 88 (5%)	1 - 8	3 / 32 (9%)	0 / 32 (0%)
Xylene	10000	3 - 18000	19 / 88 (22%)	2 / 88 (2%)	3 - 33	4 / 32 (13%)	0 / 32 (0%)
<i>Semivolatile Organics</i>							
1,2-Dichlorobenzene	--	10 - 28	2 / 23 (9%)	N/A	0 - 0	0 / 2 (0%)	N/A
2-Methylphenol	--	3 - 100	5 / 23 (22%)	N/A	0 - 0	0 / 2 (0%)	N/A
4-Methylphenol	--	70 - 88	2 / 23 (9%)	N/A	0 - 0	0 / 2 (0%)	N/A
2,4-Dimethylphenol	--	23 - 54	2 / 23 (9%)	N/A	0 - 0	0 / 2 (0%)	N/A
Naphthalene	--	2 - 43	3 / 23 (13%)	N/A	0 - 0	0 / 2 (0%)	N/A
2-Methylnaphthalene	--	1 - 5	3 / 23 (13%)	N/A	0 - 0	0 / 2 (0%)	N/A
Diethylphthalate	6	0.9 - 0.9	1 / 23 (4%)	0 / 23 (0%)	0 - 0	0 / 2 (0%)	0 / 2 (0%)
Di-n-Butylphthalate	6	0.6 - 1	2 / 23 (9%)	0 / 23 (0%)	0 - 0	0 / 2 (0%)	0 / 2 (0%)
bis(2-Ethylhexyl)Phthalate	6	1 - 190	7 / 23 (30%)	3 / 23 (13%)	1 - 8	2 / 2 (100%)	1 / 2 (50%)

bedrock aquifer (including Galena-Platteville and St. Peter aquifers) wells. A map showing the distribution of TCA is presented in Figure 4-31 for both the unconsolidated and bedrock aquifers. Examination of this map reveals a number of different areas where elevated concentrations of TCA are present in groundwater. The most extensive continuous area of elevated concentrations of TCA underlies locations a short distance west of source Area 7, and extends downgradient (west-northwest) to about 9th Street.

The highest concentrations of TCA detected in Phase II samples are located immediately downgradient of source Area 7, at MW135 (8,000 ppb) and MW106A (7,900 ppb). Other wells a short distance downgradient of Area 7 have high TCA concentrations, such as at MW134A (860 ppb), MW105B (160 ppb), and MW105A (61 ppb). In contrast, wells located upgradient of Area 7 (MW112A and B, MW108A, B and C, MW122A and B, and MW136) show low or undetectable concentrations of TCA. Concentrations of TCA in the area just downgradient of Area 7 are elevated across a broad area transverse to the groundwater flow direction (at least 1,200 feet south to north, from MW135 to MW105). This is consistent with the soil gas and subsurface soil sampling results, which show that a similar-sized portion of Area 7 has elevated TCA concentrations. Elevated concentrations at MW105 (located 350 feet north of SB7-24) suggest that subsurface contaminated soils extend somewhat farther north from the area that was sampled in the soil gas and subsurface soil sampling programs. As noted in the description of the results of those sampling efforts, the northern and northwestern extent of contamination in Area 7 were not completely defined. Based on high subsurface soil contamination at SB7-24 but not at other nearby borings, this northern area may have a localized distribution of contamination, without the consistently high contaminant levels observed south of the basketball courts. This is consistent with: 1) moderate to low concentrations of TCA at MW105 and MW134; 2) erratic soil gas concentrations across the northern end of the area surveyed (i.e., near the playground); and 3) evidence from aerial photos showing less disposal activity in the northern area than in the area south of the playground.

Downgradient of MW135, MW106, MW134, and MW105, TCA concentrations decline fairly steadily to the west-northwest (see Figure 4-31). The axis of the contaminant plume proceeds to the west-northwest, passing near MW133 (MW133B contained 1,200 ppb TCA) and MW101 (MW101A, B, and C had between 560 and 650 ppb), and then turning westward to pass near MW37 (230 ppb). The plume retains its width of about 1,500 feet (at the 100 ppb contour) at MW103, MW133, and MW102, the three well nests located approximately 2,000 feet downgradient of Area 7. The broad zone of lower TCA concentrations north of the plume's center is apparently present in this area as well (near MW102C). This regular pattern suggests that the TCA contamination between MW106 and MW37 constitutes a single plume downgradient from Area 7 (hereafter referred to in the text and figures as the Area 7 plume). Evidence from patterns of other contaminants supports this idea (discussed later in this subsection), as well as the vertical pattern of TCA distribution (discussed in the following paragraph).

In the area immediately downgradient from Area 7, TCA is primarily limited to the unconsolidated aquifer, and to the upper 60 feet of the subsurface (see Figure 4-31). For instance, TCA is much more abundant in MW106A, MW134A, and MW105A and B than in the deeper wells of each well nest. This pattern is consistent with a nearby source for the observed

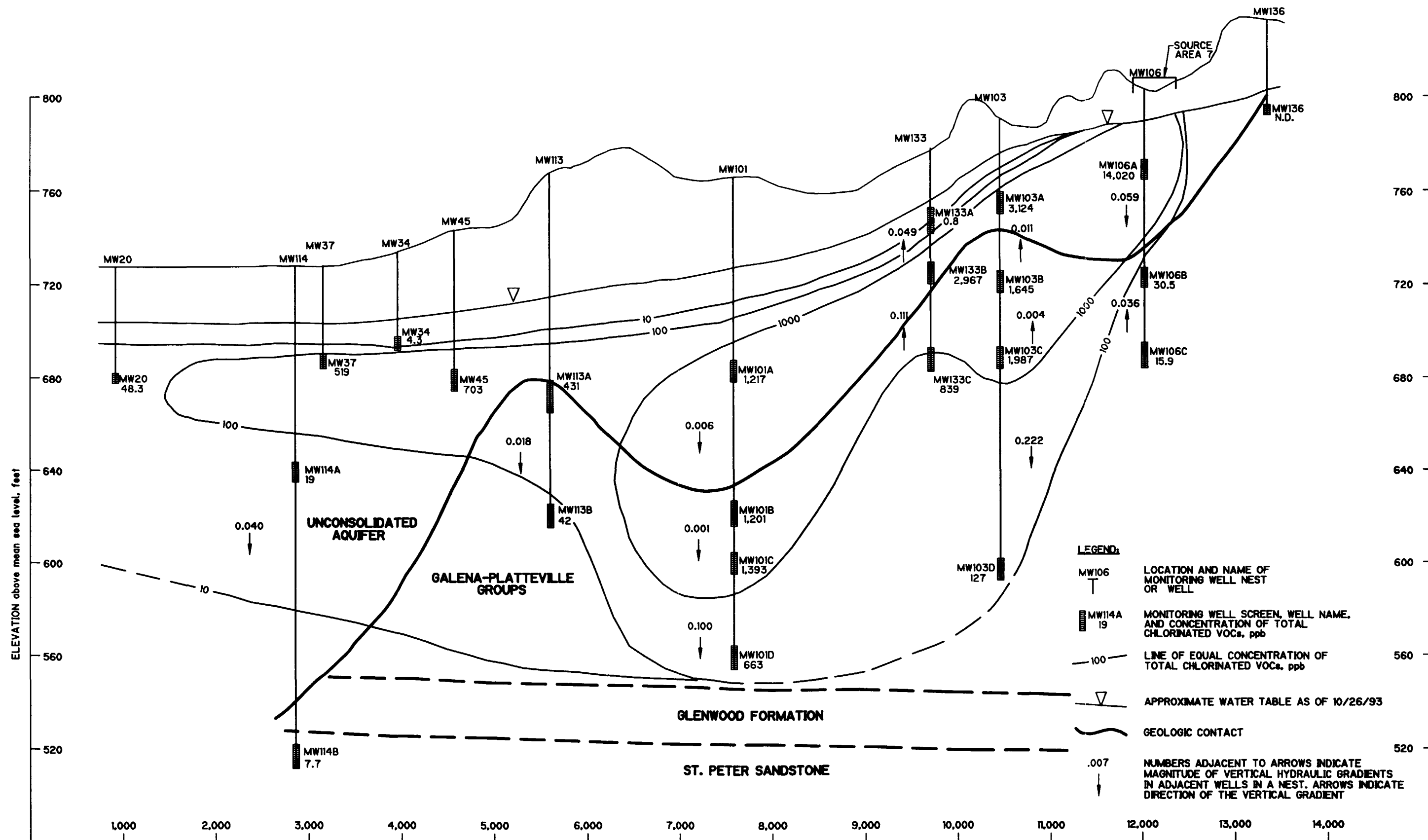
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FIG 4-32

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SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY
CROSS-SECTION ALONG LENGTH OF
AREA 7 CONTAMINANT PLUME

The shape of the TCA contaminant plume from MW101 and to the west is consistent with previous sampling efforts, including the Operable Unit (CDM, 1990) and quarterly Illinois State Water Survey (ISWS) sampling of ISWS monitoring wells. This includes a southward dip in the northern 100 ppb contour near MW113 and MW34. The downgradient position of the Area 7 plume is unclear west of 11th Street (see Figure 4-31). The farthest downgradient hit of TCA in this plume in Phase II sampling was near Eleventh Street and Wills Avenue at MW21, where 100 ppb was reported. However, in Phase I and in sampling conducted by the ISWS, elevated concentrations of TCA were found west of Eleventh Street in ISWS wells monitoring wells MW30, MW39, MW42, and MW20. MW20 was sampled in Phase II and TCA was not detected; the reason for this discrepancy is not known.

While the precise location of the downgradient margin of the Area 7 contaminant plume can not be defined based on Phase II sampling, it appears that an additional source of contamination affects the shallow aquifer near Eighth Street and Harrison Avenue. Wells MW126A and MW124 contain TCA concentrations of 610 and 1,400 ppb, respectively. These concentrations are considerably higher than any in the Area 7 plume within more than one mile upgradient of these wells, and MW20 and MW127, the closest wells that are roughly upgradient, did not contain detectable TCA. Other wells near MW126A and MW124 appear to be a part of the same plume, showing TCA concentrations between 72 and 160 ppb (this plume will hereafter be referred to as the "Area 9/10 plume"). In contrast to the Area 7 plume, this Area 9/10 plume is oriented east-northeast to west-southwest. However, both plume orientations appear to be concordant with local groundwater flow directions (see Figure 3-11). The downgradient extent of the Area 9/10 plume is unclear, due to the lack of adequate downgradient monitoring wells. However, it appears that this plume may extend to IW19, but not as far as MW117, based on plume fingerprint evidence such as the ratios of TCE to TCA and PCE to TCA (see discussion under TCE and PCE).

In addition to elevated TCA concentrations in MW126A and MW124 compared to upgradient wells, other lines of evidence support a nearby source for the TCA in these wells. This evidence includes the concentrations of other compounds (see discussion of PCE), and soil gas survey results in Area 9. The soil gas sampling in Area 9 showed moderately high (91 to 120 µg/L) concentrations of TCA, PCE, and TCE at a location approximately 250 feet north-northwest of MW125. Subsurface sampling at that location showed evidence of minimal contamination by PCE (5 ppb). Additional investigation near a manufacturing facility to the east was desired, but access was not possible. It is possible, therefore, that a contaminant source may exist on or adjacent to this facility; the location (north of Harrison Avenue and between Eighth and Ninth Streets) would be upgradient of the MW126A-MW124 plume (hereafter termed the Area 9/10 plume) and downgradient or side-gradient to wells MW20 and MW127, which are nearly free of chlorinated VOCs.

A third area of elevated TCA concentration in groundwater originates on the Sundstrand facility southeast of Harrison Avenue and Alpine Road (hereafter called the Area 8 plume). The TCA concentration at well IW23 (MWS5 at the Sundstrand facility) was 2,500 ppb; other Sundstrand monitoring wells upgradient of this well (sampled in Phase I and in Sundstrand sampling efforts) have low or undetectable TCA, implying a contaminant source near IW23. Elevated TCA concentrations extend from IW23 approximately to the west, to IW24, MW107, IW21, and

probably to MW104; this orientation is generally concordant with groundwater flow directions. This Area 8 plume has its own fingerprint, with low ratios of TCE to TCA (see discussion on TCE), and 1,1-DCE being an abundant daughter product (see discussion on 1,1-DCE); these patterns were noted in samples from Phase I, when more samples were collected from this plume. The downgradient margin of the Area 8 plume appears to extend to MW104, where MW104B and C have contaminant fingerprints typical of this plume. The origin of VOC contamination at MW122 is not clear. The contaminant fingerprint of well MW122A is different from that characteristic of the Area 8 plume, but is more like that of the Area 7 plume (see discussion on TCE and 1,1-DCE). In addition, it is likely that the northern boundary of Area 7 extends farther north than the currently known boundary, as evidenced by waste piles observed north of the playground. This suggests that it is possible that Area 7 is a source for groundwater contamination at MW122. Conversely, MW122 is not located hydraulically downgradient of the currently known extent of Area 7, suggesting that contamination could be originating from the Area 8 direction. It is also possible that localized low-permeability units could affect contaminant migration paths such that contaminants (i.e., DNAPL) move counter to known groundwater flow directions. DNAPLs are largely influenced by gravity and they tend to move downslope along the top of low permeability units, even if the direction of movement is not parallel to groundwater flow. Although DNAPL was not identified in this investigation, the possibility of DNAPL-related contaminant migration at MW122 should not be eliminated.

A fourth area of elevated concentrations of TCA in groundwater exists downgradient from Area 4. At MW130, TCA was reported at 1,000 ppb. This well is located about 350 feet downgradient of Area 4. Surrounding upgradient and side-gradient wells such as MW22 and MW32 contained less than 25 ppb of TCA, and wells in the Area 7 plume to the south had no more than 310 ppb of TCA. Therefore, a separate TCA plume appears to originate beneath Area 4 (hereafter termed the Area 4 plume), which is also suggested by the subsurface soil and soil gas data in Area 4 (see subsections 4.5 and 4.2, respectively). This plume extends from Area 4 to the west-northwest, concordant with local groundwater flow, as well as being parallel to the Area 7 plume.

The Area 4 plume has its own distinctive fingerprint, as TCA constitutes more than 95% of total detected VOCs. A similar, distinctive fingerprint for Area 4 contamination was also noted for subsurface soil samples (see subsection 4.5). Other wells in this plume and downgradient from MW130 include a private well at 1817 Harrison Avenue (991 ppb of TCA, sampled in June 1990 in the Operable Unit; CDM, 1990) and a residential well at 1713 Harrison Avenue (50 ppb of TCA, sampled in June 1993 in Phase II). Concentrations of TCA are also elevated at IW11 (860 ppb of TCA in Phase II). At IW11, however, an additional contaminant source affects groundwater, causing high concentrations of non-chlorinated VOCs, which in turn caused high detection limits for TCA at nearby wells MW128 (detection limit 250 ppb) and IW10 (detection limit 20,000 ppb). In addition, for TCE, there appears to be a local subsurface soil contaminant source in Area 11. Though TCA was not found in subsurface soils in Area 11, its presence could have been obscured by high detection limits in some samples (see subsection 4.5). As a result, the high detection limits for TCA in both groundwater and soil obscure the question of the source of elevated TCA concentrations at IW11. The data are consistent with a TCA source in Area 4, but an Area 11 source cannot be ruled out. The downgradient extent of the Area 4 plume is thus not known with accuracy. However, the concentrations in Area 11 (at IW11) end

within about 1,000 feet to the west: well MW127, located roughly downgradient from Area 11, had no detectable TCA (detection limit 12 ppb).

Several other instances of elevated TCA concentrations in groundwater were reported from Phase II wells. Of these, the highest concentration was at IW5 (370 ppb) on the former Acme Solvents facility (Area 13). This Area 13 plume cannot be readily defined as an extensive TCA plume based on the available data, because of sparse well coverage. The well containing the highest concentrations of other VOCs (IW1) had undetectable TCA at the elevated detection limit of 6,200 ppb; as a result, the maximum concentration of TCA from this source is not known. Well MW132 is located approximately downgradient of Area 13 and showed a very low TCA concentration (0.6 ppb). Based on this result, any TCA contamination that originates from Area 13 either ends before reaching MW132, or passes north of MW132.

A TCA concentration of 190 ppb was detected at IW14, located at the Erhardt-Leimer facility. This area of groundwater contamination is referred to as the Area 15 plume. The contamination was discovered recently by the owner and reported to the IEPA; remediation is ongoing. Because of sparse well coverage in this area, the direction of TCA migration from Erhardt-Leimer is not known; however, based on groundwater gradients, the most likely direction is to the west or southwest (see Figures 3-11 and 3-12). The downgradient extent of TCA from this source is limited, based on low-ppb concentrations at MW108, located roughly downgradient from the Erhardt-Leimer facility.

Apart from the TCA detections in the various plumes and contaminated areas noted above, TCA was detected at the following wells: MW116B (48 ppb), MW111B (40 ppb), MW102A (34 ppb), MW43 (33 ppb), MW19 (21 ppb), MW112A (18 ppb), and MW111A (18 ppb). Of these, MW116B and MW43 are near each other, have similar ratios of contaminants, and are probably part of the same plume. Whether this area of contamination is an identifiable plume or not, for ease of discussion and presentation it is termed the Area 16 plume. The source of this plume is unknown, however, because of sparse well coverage upgradient (northeast) of these wells. The source is most likely not very near to MW116, because the shallow well at this location (MW116A) contained a low (1 ppb) concentration of TCA. Contamination at MW112A is located quite near hits of TCA in soil gas and subsurface soil samples in the northeastern part of Area 7, and thus may represent low-level TCA present in the upgradient portion of the Area 7 plume.

The elevated TCA concentration found at MW102A may be related to the Area 7 plume located upgradient. Although MW102A may be screened in a locally perched zone of the unconsolidated aquifer it is directly downgradient of an Area 7 source. The sand zone screened by MW102A appears to be connected to a coarse sand-sand gravel zone which extends upgradient toward Area 7 at MW105, MW108, and MW111 (see Figure 3-3 in CDM, 1992). TCA concentrations at MW102A appear to be consistent with concentrations observed at similar depths in the Area 7 plume at this distance from the Area 7 source (see Figure 4-32). In addition, the TCE/TCA ratio observed in the groundwater sample collected from MW102A (0.18) is consistent with ratios observed in groundwater samples collected from MW105 and MW134, located directly upgradient from MW102.

TCE

Trichloroethene (TCE) was the second most frequently detected compound in Phase II groundwater samples, having been detected in 62 of the 88 (70%) unconsolidated wells and 17 of the 32 (53%) bedrock aquifer wells sampled. TCE is used in a wide variety of applications, including metal degreasing, an extraction solvent for oils, fats, and waxes, solvent dyeing, dry cleaning, a refrigerant and heat-exchange liquid, a fumigant, cleaning and drying electronic parts, a diluent in paints and adhesives, in textile processing, as a chemical intermediate, and in aerospace operations (flushing liquid oxygen). Though only the third or fourth most abundant contaminant overall in groundwater of the study area, TCE had the highest number of detections above its Maximum Contaminant Level (MCL) of 5 ppb, with 40 unconsolidated wells and 14 bedrock aquifer wells above this level. As illustrated in Figure 4-33, which displays maximum TCE concentrations at each well nest or well, the distribution of TCE in the groundwater has many similarities to that of TCA. The broadest area of elevated concentrations of TCE is located downgradient from Area 7. Similar to TCA, the highest TCE detections near Area 7 are found a short distance downgradient of Area 7 (at 650 ppb in MW135); contouring of the TCE concentrations yields a plume with similar shape as the Area 7 TCA plume. Consequently, in further discussion of TCE in this area, the contamination will be referred to as the Area 7 plume.

One difference between TCE and TCA is that there was no TCE detected in MW106A, while the second-highest TCA detection was reported from that well (7,900 ppb). This difference was also noted in the Phase I sample. The explanation for this is two fold. Phase II soil gas sampling shows that the area of the basketball courts, approximately upgradient from MW106, is low in TCE relative to TCA: ratios of TCE to TCA in the five samples adjacent to the basketball courts are less than 0.07, while most samples to the south have ratios between 0.15 and 0.35. The pattern is repeated in subsurface soils: in SB7-3, 7-3, 7-5, and 7-22 from near the basketball courts, ratios of TCE to TCA are 0.12 or less, while most subsurface samples to the north or south have ratios of 0.15 to 0.65. Based on this evidence, the lack of detected TCE in the groundwater sample from MW106A may be a result of low TCE concentrations in source material immediately upgradient. This interpretation is consistent with the fact that wells south and north of MW106 (comprising MW135, 134, and 105) do contain detectable TCE; this is to be expected, considering that they are located downgradient of portions of Area 7 which contain proportionally higher TCE concentrations in soil gas and subsurface soils than in the area upgradient of MW106 (the basketball courts). An alternative explanation for the lack of detectable TCE in the MW106 groundwater sample is based on the method detection limit used to quantify TCE at this location. In both Phase I and Phase II investigations the groundwater sample collected from MW106A was diluted to quantify higher concentrations of other VOCs. Method detection limits for the Phase I sample was 71 ppb while the method detection limit for the Phase II sample was 330 ppb. TCE concentrations observed in the aquifer at lateral locations during both the Phase I and Phase II investigations were well below the detection limits used to quantify TCE at MW106A. Based on the distribution of TCE in the aquifer at other monitoring wells in the vicinity of MW106A, it is a very distinct possibility that TCE is present in the aquifer at MW106A at concentrations below the higher detection limits used to quantify the sample.

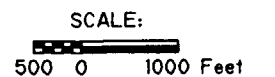


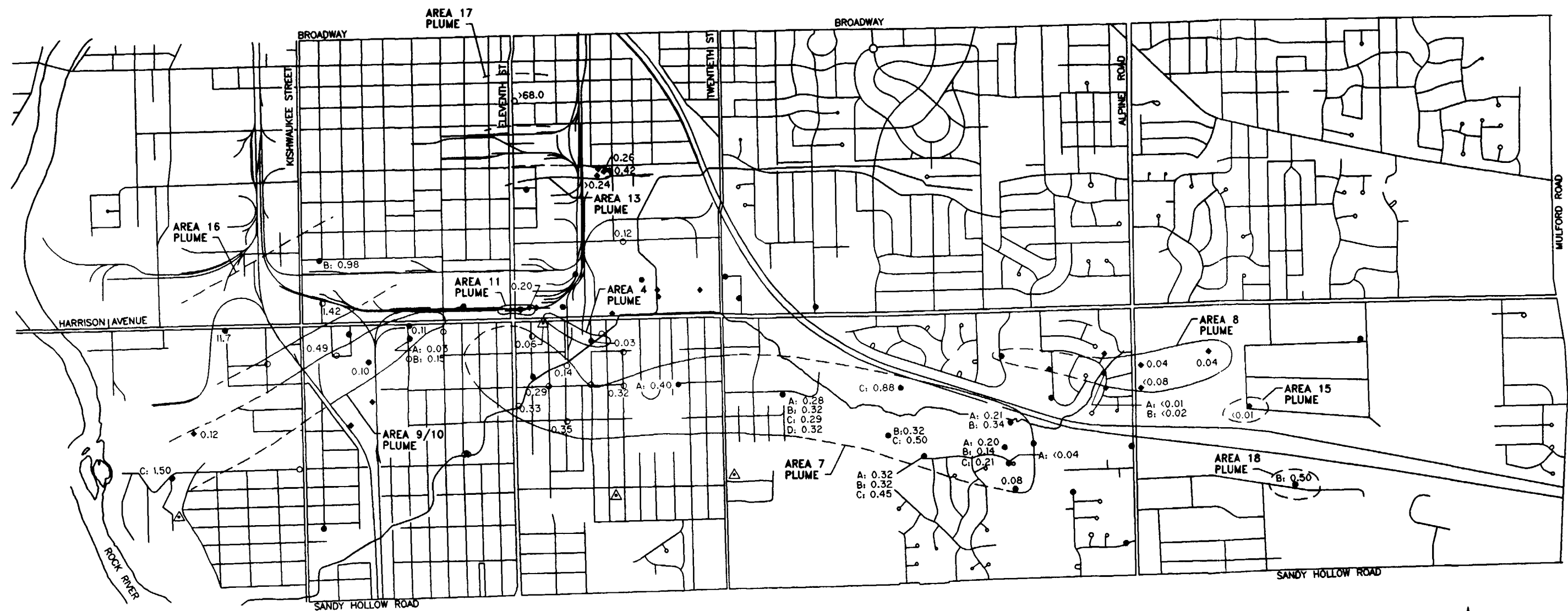
Figure No. 4-33

In wells located upgradient from Area 7, TCE was detected, if at all, at very low concentrations (5 ppb at MW112A and B, MW108A and B, MW122A and B, and MW136). Downgradient from Area 7, the TCE Area 7 plume has a width of about 1,500 feet at the 100 ppb contour (similar to its width adjacent to Area 7). Similar to TCA, TCE concentrations decline gradually in the downgradient direction, and the plume's center passes near MW103, 133, 101, and MW37. The TCE plume is shallow near Area 7, primarily confined to the upper 60 feet of the subsurface (and mainly in the unconsolidated aquifer), and gradually moves deeper in the downgradient direction, at least as far as MW133. Similar to TCA, however, TCE concentrations in the deeper part of the dolomite aquifer (MW113B) are considerably less than those in the shallower part of the unconsolidated aquifer (MW113A).

Throughout the Area 7 plume, TCE is present at similar proportions to TCA. In all Area 7 groundwater samples where TCE or TCA is present at 25 ppb or higher (except for MW106A), the ratio of TCE to TCA is between 0.08 and 0.88; in most cases (21 of 24 wells), this ratio falls within a more limited range of 0.13 to 0.50 (see Figure 4-34). The TCE/TCA ratio is not shown for low-contamination wells where both TCE and TCA were reported at less than 25 ppb; though ratio patterns established for the higher-concentration locations also generally hold for the ratios in low-concentration wells, greater fluctuation of the ratio at these low concentrations tends to obscure the patterns defined at the locations of higher concentrations. The latter locations are most influential in terms of total contaminant mass, and are thus given the most significance. The relative constancy of the TCE/TCA ratio in the Area 7 plume, also observed in Phase I and in ISWS sampling, suggests that the Area 7 plume originates primarily from a single source. This idea is consistent with the patterns established for TCA and TCE (and other contaminants discussed below) that show a plume migrating downward in the direction downgradient from Area 7, with gradually declining contaminant concentrations.

The use of the ratio of TCE to TCA can be helpful to discriminate between different contaminant sources. TCE and TCA are not related by any known natural degradation process, tend to persist in the subsurface, and have similar physical and chemical properties (solubility, sorption coefficient, susceptibility to degradation) that result in mobile behavior in many groundwater environments (these processes are discussed in more detail in subsection 4.9). TCE/TCA ratios of a contaminant plume can be affected by the mixing of two plumes with varying quantities of TCE or TCA making it difficult to quantitatively distinguish between plumes if the effect of mixing results in similar TCE/TCA relationships. The Area 7 TCA plume appears to be mixing with the Area 4 and Area 11 plumes which may account for the low TCE/TCA ratios observed in these plumes. However, the resultant TCE/TCA relationships which exist between the plumes are still anomalously different. Biodegradation of the TCE or TCA component of a plume which may occur at downgradient locations should be considered when applying TCE/TCA ratios to distinguish between plumes. TCE/TCA ratios may be anomalously different, however the 1,2-DCE or 1,1-DCA component of a plume may still be mixing with another plume. Therefore, the distribution of degradational components of a compound within a contaminant plume and between contaminant plumes should be considered when making conclusions based on these types of ratios.

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FIG 4-34
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NOTES:

1. TO REDUCE CLUTTER ON THE MAP, FULL WELL NAMES ARE NOT INCLUDED; REFER TO FIGURE 3-3 FOR ALL NAMES
2. TCE/TCA RATIOS ARE GIVEN ONLY FOR SAMPLES WHERE EITHER TCE OR TCA WAS PRESENT AT 25 PPB OR GREATER.

LEGEND:

- 0.14 ISWS MONITORING WELL WITH RATIO OF TCE TO TCA
- A: 0.21 CDM/IEPA MONITORING WELL OR WELL NEST; LETTER INDICATES A SPECIFIC WELL IN THE WELL NEST
- B: 0.34
- ◆ ON-SITE INDUSTRIAL SUPPLY WELL OR MONITORING WELL
- △ RESIDENTIAL WELL LOCATION
- GENERALIZED PLUME OUTLINE



SCALE:
500 0 1000 Feet

SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY

TCE/TCA RATIO
IN PHASE II GROUNDWATER SAMPLES

As observed in the Area 7 plume, TCE and TCA have migrated a similar distance, to the area between MW21 and MW20 (supported by more-detailed ISWS sampling in this area, at MW39 and MW42); this indicates similar contaminant velocities and similar retardation rates for TCE and TCA in this plume during migration. The Area 7 contaminant source has been characterized through soil gas sampling and subsurface soil sampling (see subsections 4.2 and 4.5): these sampling efforts have shown that both TCE and TCA are present in source subsurface soils, and TCE/TCA ratios are generally between 0.15 and 0.65 (particularly in subsurface samples of the highest concentrations; these areas have the greatest influence on contaminant ratios in groundwater). The fact that TCE/TCA ratios are relatively consistent throughout the Area 7 plume, combined with the fact that these ratios are similar to those defined in subsurface soils and soil gas in Area 7, suggests that the TCE/TCA ratio reflects the contaminant source material, and that this ratio is characteristic of the Area 7 plume. This idea is supported by the fact that most other plumes have groundwater samples with TCE/TCA ratios outside the range of those found in the Area 7 plume, as shown in Figure 4-34. This figure shows generalized plume outlines for each defined or inferred contaminant plume of chlorinated VOCs; the figure is useful in determining whether, and how, the identified contaminant plumes could be connected.

Elevated concentrations of TCE were found in seven of the eight areas or plumes defined as containing elevated TCA concentrations outside the Area 7 plume, and in two plumes where TCA was not noted. The highest of the TCE concentrations observed in Phase II samples was at Area 13, where IW1 contained 1,500 ppb. As with TCA, the downgradient extent of this contamination is not known due to the lack of sufficient monitoring points. However, any connection with the residential area south of Harrison Avenue would only be far downgradient and to the west, such as in the Area 16 plume. This is based on groundwater flow directions, and on the lack of significant detections directly between Area 13 and the residential area.

The Area 9/10 plume defined for TCA is not as clearly defined for TCE. Local spikes in TCE concentrations across this area suggest that a TCE source may exist in this area. As discussed under TCA, one nearby soil gas sample (from near the upgradient extent of the Area 9 TCA plume) contained an elevated concentration of TCE (91 µg/L) as well as elevated TCA and PCE.

The Area 4 plume that was defined for TCA displays slightly elevated concentrations of TCE. TCE/TCA ratios are especially useful in the Area 4 plume, because they show consistently low values for all media from which samples were collected: soil gas, subsurface soil, and groundwater samples. The groundwater samples include MW130 (TCE/TCA ratio is 0.03) and the residential well at 1713 Harrison Avenue (TCE/TCA ratio is 0.06); the June 1990 residential well sample from 1817 Harrison Avenue also had a TCE/TCA ratio of 0.06 (CDM, 1990).

As noted for TCA, however, the downgradient extent of the Area 4 plume is unclear. Several hundred feet downgradient from the residential well samples noted above is the Area 11 source of aromatic VOCs; based on the detection of 410 ppb of TCE in sample SB11-7G, Area 11 is also apparently a source of TCE to groundwater. This TCE source is probably limited in extent and concentration, based on the fact that no other Area 11 subsurface soils contained elevated TCE (though detection limits were elevated in some samples). Nevertheless, a localized TCE source is consistent with the elevated TCE detection in nearby well IW11 (170 ppb of TCE). TCE was present at much lower concentrations in the upgradient Area 4 plume and other wells

approximately upgradient from IW11 (MW129, MW22, MW38); this is also consistent with the idea of a nearby source of TCE for the detection in IW11. Well IW11 also contained elevated TCA (860 ppb) in the Phase II sample. The location of this sample is approximately downgradient from the Area 4 plume. The TCA in IW11 could have originated from the Area 4 plume, which contained up to 1,000 ppb in the sample about 1,300 feet upgradient (at MW130); there is no evidence that TCA is emanating from an Area 11 source. Therefore, it appears that groundwater contamination at IW11 is a mixture of contaminants originating from separate sources in Area 11 (the likely TCE source) and Area 4 (the likely TCA source).

The strength of the Area 11 TCE source (i.e., the quantity of TCE present, based on extent and concentrations in subsurface soils) is not great compared to several other contaminant sources in the study area, because the TCE plume at Area 11 is not extensive or concentrated: well MW128, located 140 feet west (approximately downgradient) of IW11, showed no detection of TCE at a detection limit of 250 ppb. This sample was diluted due to the presence of ppm levels of ETX compounds. The downgradient extent of the Area 11 TCE plume probably does not extend to wells MW127 (detection limit of 12 ppb) and MW20 (detection limit of 1 ppb) located approximately downgradient from Area 11. Based on these patterns, chlorinated VOCs in Area 11 do not appear to affect the residential area south of Harrison Avenue. However, as discussed under other VOCs, aromatic VOCs (toluene, xylene, and benzene) originating in Area 11 appear to have more extensive effects on downgradient groundwater quality.

A fifth area of TCE contamination of groundwater appears in the Area 8 plume (Sundstrand plume). TCE detections were noted in two wells (IW23 and IW24) at 89 and 12 ppb, respectively. This is another area where the TCE distribution pattern differs from that of TCA. In the Area 8 TCE plume, TCE concentrations greater than 1 ppb were not observed west of the facility boundary at Alpine Road; TCA, on the other hand, was present in several wells west of Alpine Road. The difference in the extent between the TCE to TCA plumes in this area may account for the characteristically low ratios of the TCE and TCA in the Area 8 plume. As shown in Figure 4-34, the TCE/TCA ratio was less than 0.08 in Phase II wells in the Area 8 plume; low ratios were also noted during Phase I. This Area 8 plume therefore has its own contaminant fingerprint, with low ratios of TCE to TCA (less than 0.08); in addition, 1,1-DCE is an abundant daughter product (see discussion on 1,1-DCE); these patterns were also noted in samples from Phase I, when more samples were collected from this plume. The downgradient margin of the Area 8 plume appears to extend to MW104, where MW104B and C have contaminant fingerprints typical of this plume. As discussed for TCA, the origin of VOC contamination at MW122 is not clear.

As shown in Figure 4-33, four other areas or plumes of TCE contamination exist in the study area. However, the extent of these areas of TCE groundwater contamination and the location of the source areas are not well known. Among these four final plumes, the highest concentration (82 ppb) was found in well MW121 in the Area 16 plume near the western boundary of the study area. Other wells approximately upgradient (MW116B, MW43) contained elevated TCE, as was noted for TCA. The elevated concentrations in these wells, as well as their high TCE/TCA ratios relative to other wells, suggest that these contaminants are in a separate plume than wells to the east. The extent of this contaminated area is not known, but it most likely connects with

the TCE-PCE contamination observed in residential wells on Rock River Avenue to the south (CDM, 1990).

TCE was detected at 68 ppb in MW1 in the northern portion of the study area, in a well where TCA was not detected. In the plume figures, this contamination is referred to as the Area 17 "plume," even though TCE contamination at this single location cannot be reliably defined as a plume (i.e., connected to contamination in other wells). MW1 is an ISWS well which is part of a well nest with MW2 (shallow well) and MW5 (deep well), where contaminants have generally been limited to the moderate-depth well (MW1, at about 50 feet below the water table). The moderate depth of contamination at this location suggests a source some distance upgradient. As discussed below, PCE was also detected in well MW1; TCE-PCE contamination was also noted in groundwater samples collected from 1982 through 1985 from nearby municipal well UW7A located about 250 feet to the south (Wehrmann, 1988). The TCE-PCE contamination at this location is consistent with the contaminant source being located at potential source Area 12 (Viking Chemical). This potential source area is located roughly upgradient of MW1, and contains subsurface soils with high PCE, TCE, and TCA. However, the evidence is not conclusive, because groundwater flow directions are not known accurately, and TCA was not detected in MW1, while it was present as the third-most abundant compound in Area 12 subsurface soils.

TCE detections were noted at MW111A and B (16 and 20 ppb, respectively), wells where TCA was also observed. This contamination is a single-location occurrence like Area 17, and is referred to as the Area 18 plume. This is an area with no known history of industrial activity or disposal. The lack of detectable TCE in surrounding areas (such as in the Area 15 plume to the northwest) and the shallow depth of contamination (upper 75 feet) show that the Area 18 "plume" is an isolated contaminated area, and suggests a local source for the contamination.

A single elevated TCE concentration of 14 ppb was reported for MW140 (Area 19 "plume"). This well is located about 300 feet downgradient of Suntec Industries; based on reports submitted to IEPA, near-surface soils in the western portion of this facility contain TCA, TCE, and PCE. Suntec has been operating a soil vapor extraction system in the area as a remedial measure for the soils. The detection of TCE at MW140 combined with lower concentrations in wells upgradient (IW9, MW142) suggests that some of the TCE in near-surface soils at Suntec is migrating in groundwater. Soil vapor extraction is not an effective technology for a groundwater remediation. The downgradient extent of the Area 19 plume is not known, as contaminant concentrations are quite low.

All other detections of TCE not noted above are at less than 10 ppb; many of these are most likely in dispersed portions of the Area 7 plume, such as those found in the residential area between Twentieth and Ninth Streets. As discussed under TCA, some southward migration of the Area 7 plume may have resulted from pumping at municipal well UW35 (the location of MW9, MW29, and MW118). The proportion of contaminants at these wells (TCA > TCE) is consistent with observation of the Area 7 plume. A dispersed Area 7 plume may account for the TCE detections near and west of Twentieth Street and Harrison Avenue (such as IW9, MW32, and MW17), as well as for detections just upgradient of the main area of contaminated

subsurface soils in Area 7 (MW112A and B, MW122A). The presence of both TCE and TCA in these wells is characteristic of the Area 7 plume.

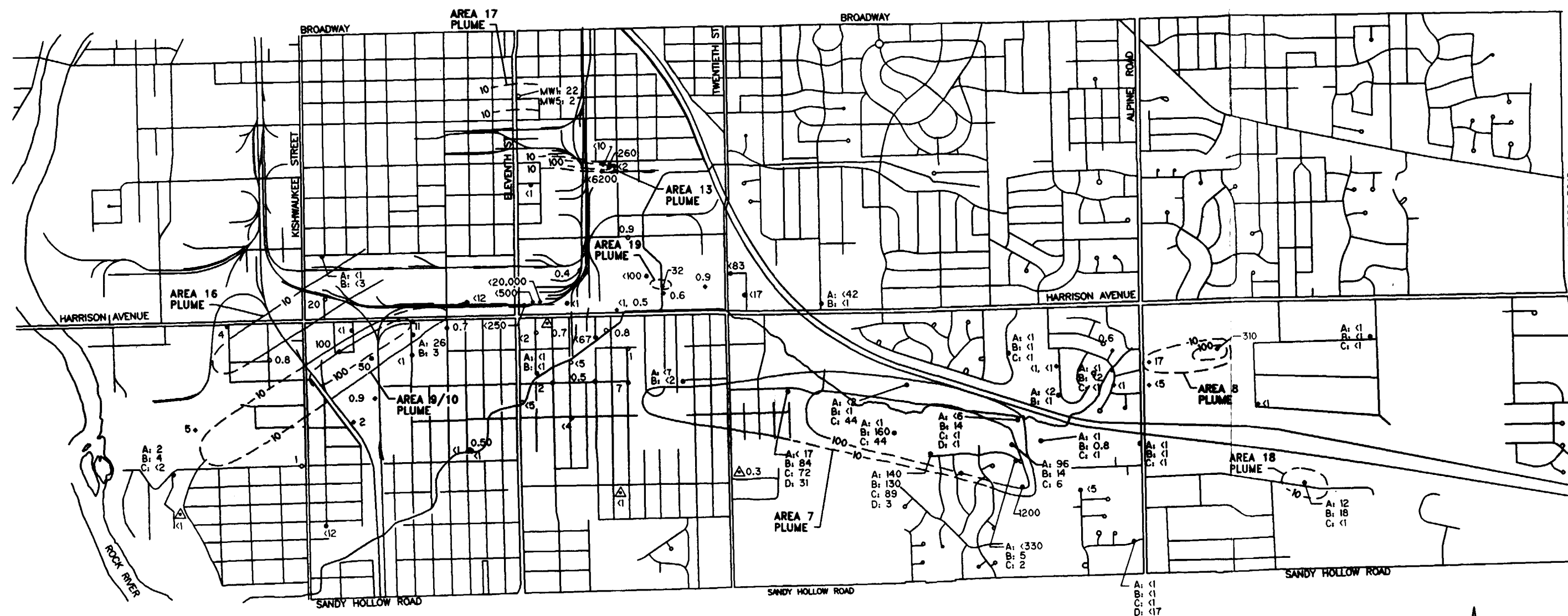
PCE

Tetrachloroethene (PCE) was detected in Phase II groundwater samples from 40 of 88 (45%) unconsolidated aquifer wells, and from 14 of the 32 (44%) bedrock aquifer wells sampled. PCE is used as a dry-cleaning solvent; in degreasing and drying metals and other solids; as a solvent for waxes, greases, fats, oils, and gums; in manufacturing printing inks and paint removers; in preparation of fluorocarbon and trichloroacetic acid; in vermifuge; and in organic synthesis. Of the 54 wells with detections of PCE, 19 wells in the unconsolidated aquifer and 10 in the bedrock aquifer were above the MCL for PCE, which is 5 ppb. The distribution of PCE in wells sampled in Phase II is presented in Figure 4-35. The highest concentration (1,200 ppb at MW135) and the most extensive area of detections of PCE was in the area hydraulically downgradient from Area 7. As depicted in Figure 4-35, this area occupies much of the same territory underlain by the Area 7 TCA and TCE plumes. Throughout the zone from Area 7 to the MW101 well nest, PCE has similar distribution patterns as those of TCA and TCE. These include a similar position of the plume's center line, a gradual downward migration of the plume's center of mass, and a gradual attenuation of contaminant concentrations in the downgradient direction. Throughout this area, PCE concentrations generally parallel those of TCA and TCE: in 13 of 16 wells, the ratio of PCE to TCA falls within the relatively narrow range of 0.09 to 0.16.

Downgradient of the MW101 nest, PCE/TCA ratios in Phase II samples were significantly lower, being 0.01 or 0.02 where PCE was detected. The declining ratio of PCE to TCA west of MW101 suggest that PCE has been proportionally more rapidly attenuated in the Area 7 plume than TCA (or TCE). A slower migration rate for PCE relative to TCA and TCE is commonly seen at sites of groundwater contamination, and probably relates to the lower solubility of PCE than TCA and TCE, and to a higher tendency toward sorption onto aquifer solids. In the study area, slower migration for PCE than TCA or TCE can also be observed in the Area 8 plume. The degradation of PCE to its daughter products is another factor affecting the downgradient decrease of this compound. Valid comparisons cannot be made for other plumes in the study area, either because of the limited extent of these plumes, the low number of sampling locations within each plume, or the lack of PCE in source materials (as in the Area 4 plume).

The second most abundant PCE concentration was found in the Area 8 plume, where 310 ppb was detected in IW23 (Sundstrand well MW5). The Area 8 PCE plume extends about 1,200 feet to the west (downgradient), to near the facility boundary. This plume is smaller than the Area 8 TCA plume, again showing greater attenuation of PCE relative to TCA. In the three wells with the highest TCA concentrations in the Area 8 plume (IW23, IW24, and MW107A), the ratios of PCE to TCA decline from 0.12 to 0.05 to less than 0.01.

As was observed for TCA and TCE, concentrations of PCE are elevated in an area beginning near Ninth Street and Harrison Avenue and extending southwest (downgradient; see Figure 3-11) to perhaps the area of MW117. This relatively extensive area was termed the MW126B-124 plume for TCA and TCE, and the PCE plume in this area is broadly similar in outline. Based on its slower migration than TCA and TCE in groundwater environments of the study area and the



NOTES:

1. TO REDUCE CLUTTER ON THE MAP, FULL WELL NAMES ARE NOT INCLUDED; REFER TO FIGURE 3-3 FOR WELL NAMES
2. CONTOURS ARE BASED ON MAXIMUM PCE CONCENTRATIONS AT A GIVEN WELL NEST.
3. MW14A AND B WERE NOT USED IN CONTOURING, BECAUSE THEY ARE SCREENED BELOW THE CONTAMINATED INTERVAL.

LEGEND:

- 7 ISWS MONITORING WELL WITH CONCENTRATION OF PCE, ppb
- A: <7
B: <2 CDM/IEPA MONITORING WELL NEST WITH PCE CONCENTRATION, ppb; LETTER INDICATES SPECIFIC WELL OF A WELL NEST
- 14 INDUSTRIAL SUPPLY WELL OR MONITORING WELL WITH PCE CONCENTRATION, ppb
- △ SELECTED RESIDENTIAL WELL SAMPLING LOCATION (RESIDENTIAL WELL ADDRESSES AND COMPLETE RESULTS ARE GIVEN IN SECTION 6)
- 100- CONTOUR OF MAXIMUM PCE CONCENTRATION, (ppb) AT WELL NEST OR WELL LOCATION; DASHED WHERE INFERRED.



SCALE:
500 0 1000 Feet

SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY

PCE IN PHASE II
GROUNDWATER SAMPLES

CDM

environmental engineers, scientists,
planners, & management consultants

fact that PCE is not a degradation product, PCE is especially useful in indicating proximity to a contaminant source. For instance, at MW46 and other wells in the Area 9/10 plume, elevated PCE concentrations are higher than any PCE concentrations within 1.5 miles upgradient. This abrupt increase in PCE strongly suggests the presence of a nearby contaminant source of PCE to the groundwater, as was suggested for TCA and TCE.

A single PCE detection of 260 ppb was reported for IW5 in the Area 13 "plume" (Acme Solvents). The extent of any plume originating at Area 13 is unknown; any such plume would pass north of well MW132 and, if PCE is still mobile at that point, further migrate to the southwest toward the vicinity of Kishwaukee Street and Harrison Avenue.

An elevated detection of PCE was reported for IW8 (32 ppb) on the Suntec Industries property. This detection is consistent with reports submitted to IEPA detailing near-surface soil contamination by PCE, along with TCE, TCA, and xylene. Downgradient impacts of this contamination appear to be minor, as none of the nearby downgradient samples showed concentrations greater than 1 ppb.

The detection of PCE at 22 ppb in MW1 in the northern portion of the study area (Area 17 "plume") parallels the TCE detection there. As for TCE, the deeper well of the nest (MW5) had much lower concentrations (5 ppb of PCE). Detections of PCE were also noted in nearby municipal well UW7A, located about 300 feet to the south. Elevated PCE concentrations were reported for subsurface soils collected in Area 12 (Viking Chemical), which is roughly upgradient of MW5; this suggests a possible connection between Area 12 and Area 17 contamination. The extent of the groundwater contamination beyond that observed at MW1 is unknown; however, contaminants may migrate toward the area of Kishwaukee Street and Harrison Avenue, based on general groundwater flow directions.

A final area of PCE contamination of groundwater is at MW111A and B (12 and 18 ppb, respectively; Area 18 "plume"). As postulated under the discussion of TCE, Area 18 appears to be an isolated occurrence, as the concentration and proportion of VOCs (the PCE/TCA ratios at these wells are 0.67 and 0.45, respectively) are unlike those in nearby plumes.

1,2-DCE

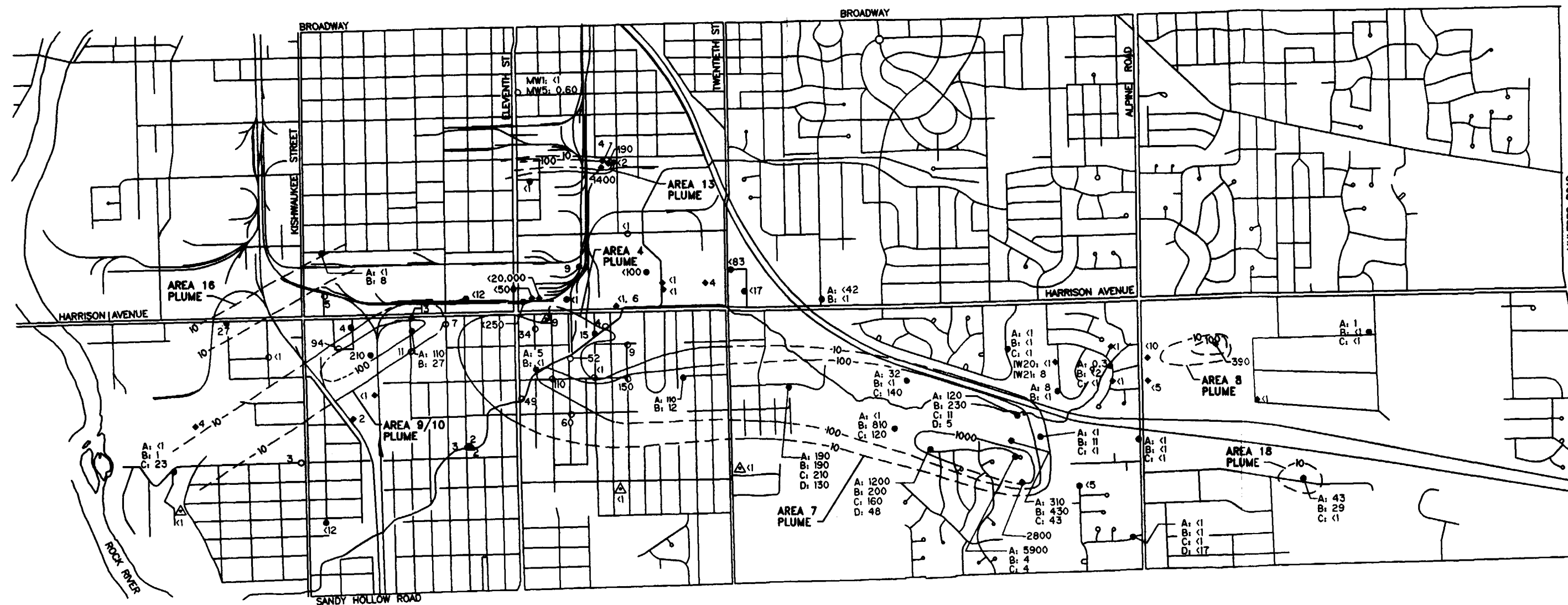
The compound 1,2-dichloroethene (1,2-DCE) is a compound that exists as two different isomers, the cis and the trans. A mixture of the cis and trans isomers is used as a solvent for fats, phenols, camphor, etc.; an ingredient in perfumes; a low-temperature solvent for sensitive substances such as caffeine; a refrigerant; and in organic synthesis. However, the production of 1,2-DCE is at relatively low volumes (less than 1,000 pounds per year; Vogel et al., 1987). The existence of 1,2-DCE in the study area may rather be a function of its formation through the biodegradation of TCE, a common contaminant in several source areas (see discussion below). In 96 Phase II groundwater samples, analyses of 1,2-DCE were isomer-specific (cis-1,2-DCE and trans-1,2-DCE), while in 24 samples the analyses were reported simply as 1,2-DCE (total). Detections of 1,2-DCE were reported for 53 of the 88 unconsolidated aquifer wells (60%), while 16 of the 32 bedrock wells (50%) displayed detections of this compound. In every case where the cis or trans isomer of 1,2-DCE was detected, cis was by far more abundant: in most of these

samples, trans was not detected (undetected in 90 of the 96 isomer-specific samples), while in cases where trans was detected, the cis isomer constituted 94% or higher of total 1,2-DCE. In samples where 1,2-DCE (total) was reported, if it is assumed that 95% of 1,2-DCE (total) is present as the cis isomer, then a total of 17 unconsolidated aquifer wells were above the MCL for cis-1,2-DCE of 70 ppb, and five of the bedrock aquifer wells were above this MCL. The highest detection of trans-1,2-DCE was 8 ppb, and thus it did not exceed the MCL in any isomer-specific analyses. It is possible that the concentration of trans-1,2-DCE could have exceeded the MCL in some samples where only 1,2-DCE (total) was analyzed, and where this concentration was high (such as at MW135). In Phase II groundwater samples, 1,2-DCE generally follows the distribution of other chlorinated organic compounds (see Figure 4-36). The highest concentrations of 1,2-DCE were found in MW106A (5,900 ppb) and MW135 (2,800 ppb), wells located immediately downgradient from Area 7. Downgradient from Area 7, concentrations of 1,2-DCE form a plume with similar shape and extent as the TCA and TCE Area 7 contaminant plumes. In the downgradient direction, the 1,2-DCE plume tends to migrate deeper in the subsurface, with significant concentrations affecting the dolomite aquifer at MW103, 133, 102, and 101. Concentrations of 1,2-DCE generally decline in the downgradient direction in the Area 7 plume.

The high concentration of 1,2-DCE at MW106A is significant in that TCE and PCE were not detected in that sample. This pattern is repeated in Area 7 in that TCE was also present at proportionally low concentrations in subsurface soil and soil gas samples from near the basketball courts, located in Area 7 and about 200 feet upgradient of MW106. In the same area, proportionally high concentrations of 1,2-DCE exist in subsurface soils from near the basketball courts (1,2-DCE was not analyzed in soil gas samples). Along with the groundwater sample from MW106A, there appear to be an inverse relationship between the abundance of TCE and 1,2-DCE in this vicinity. A possible explanation for this pattern is through degradation of a large portion of the original TCE in the highly-contaminated soils. As noted by Olsen and Davis (1990), biological degradation of TCE generally produces 1,2-DCE; as shown at other sites of chlorinated solvent contamination, this degradation proceeds most readily in an anaerobic environment in the subsurface (see Cline and Viste, 1985; Parsons et al., 1985; Vogel and McCarty, 1985); further discussion of biodegradation, including a flow chart, is presented in Figure 4-37. An anaerobic environment, or at least one with very low oxygen content, is indicated in highly-contaminated portions of Area 7. As discussed under xylene in subsection 4.5, the presence of high concentrations of readily degradable petroleum-related hydrocarbons (xylene, toluene, ethylbenzene, naphthalene) in these zones indicates low-oxygen or anaerobic conditions there. As a result, the highly-contaminated soils in parts of Area 7 have the proper conditions for the biological degradation of TCE to form 1,2-DCE.

The compound 1,2-DCE was detected in distinct areas of elevated concentration in groundwater in six of the eight areas or plumes that were defined for TCA. Elevated concentrations were not observed in the Area 11 or Area 15 plumes.

The highest concentration of 1,2-DCE outside the Area 7 plume was found in well IW1 (1,400 ppb) in the Area 13 plume, immediately downgradient of the former Acme Solvents facility. Well IW5, located upgradient of, but adjacent to, the facility, contained 190 ppb, while IW4, located about 120 feet upgradient, did not contain detectable 1,2-DCE. Similar to patterns for



NOTES:

1. TO REDUCE CLUTTER ON THE MAP, FULL WELL NAMES ARE NOT INCLUDED; REFER TO FIGURE 3-3 FOR WELL NAMES.
2. CONTOURS ARE BASED ON MAXIMUM 1,2-DCE (total) CONCENTRATIONS AT A GIVEN WELL NEST.
3. MW114A AND B WERE NOT USED IN CONTOURING, BECAUSE THEY ARE SCREENED BELOW THE CONTAMINATED INTERVAL.

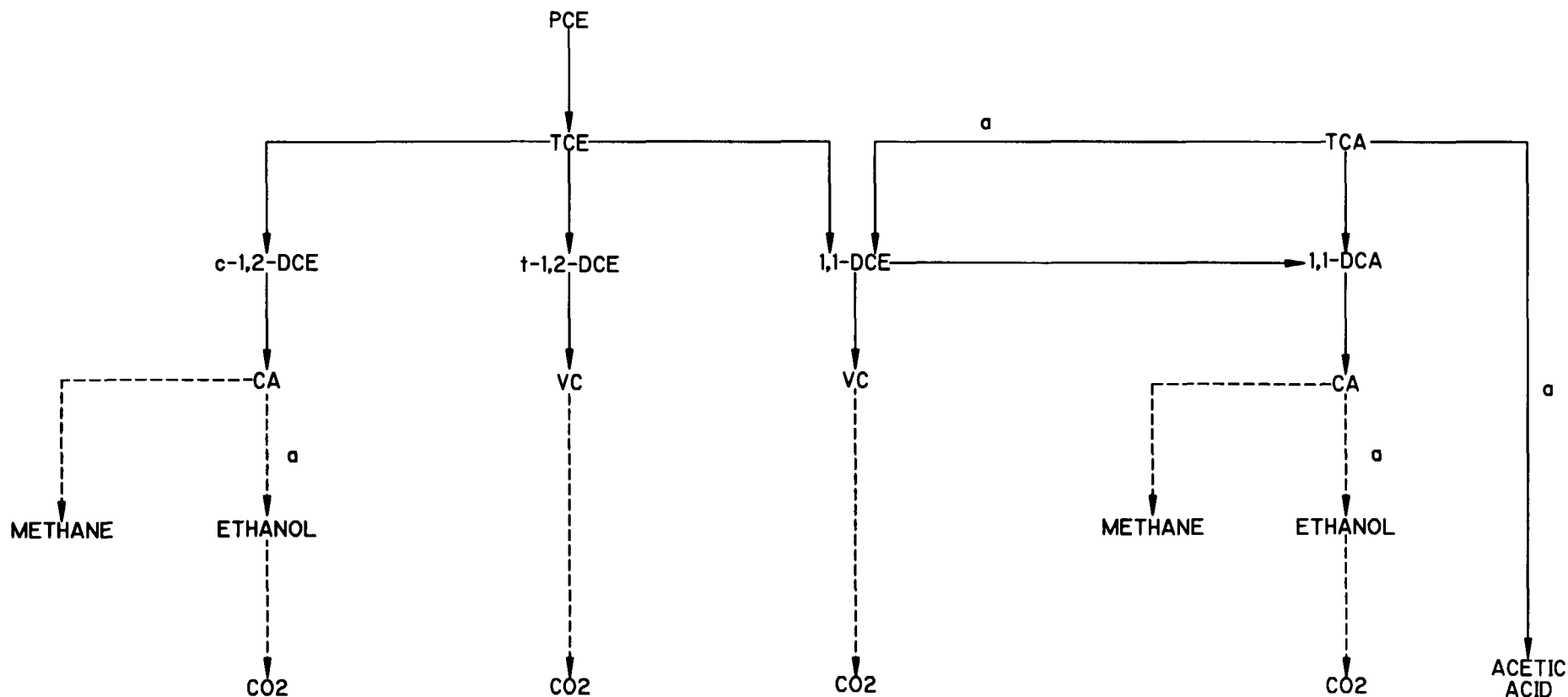
LEGEND:

- 49 ISWS MONITORING WELL WITH CONCENTRATION OF 1, 2 - DCE (TOTAL), ppb
- A: 110 CDM/IEPA MONITORING WELL OR WELL NEST WITH 1, 2 - DCE (total) CONCENTRATION, ppb; LETTER INDICATES A SPECIFIC WELL WITHIN A WELL NEST
- ◆ 8 ON-SITE INDUSTRIAL SUPPLY WELL OR MONITORING WELL WITH 1,2-DCE (total) CONCENTRATION, ppb
- △ SELECTED RESIDENTIAL WELL SAMPLING LOCATION (RESIDENTIAL WELL ADDRESSES AND COMPLETE RESULTS ARE GIVEN IN SECTION 6)
- 100- CONTOUR OF MAXIMUM 1,2-DCE (total) CONCENTRATION AT WELL NEST OR WELL LOCATION; DASHED WHERE INFERRED



SCALE:
500 0 1000 Feet

SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY
1,2-DCE (total) IN
PHASE II GROUNDWATER SAMPLES

**LEGEND**

PCE = PERCHLOROETHYLENE (TETRACHLOROETHYLENE)
 c-1,2-DCE = cis-1,2-DICHLOROETHYLENE (cis-1,2-DCE)
 t-1,2-DCE = trans-1,2-DICHLOROETHYLENE (trans-1,2-DCE)
 CA = CHLOROETHANE
 VC = VINYL CHLORIDE
 CO2 = CARBON DIOXIDE
 α = ABIOLICAL TRANSFORMATION

————— KNOWN PATHWAY

- - - - - POSTULATED PATHWAY

SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY

DEGRADATION PATHWAYS FOR CHLORINATED VOCs

CDM

environmental engineers, scientists,
planners, & management consultants

Figure No. 4-37

other contaminants, groundwater contamination originates at this facility; however, the downgradient extent of any plume cannot be defined. If an extensive plume exists, it would have to pass north of MW132 (flowing west-northwest from the facility) and then probably arc toward the southwest, generally following groundwater gradients, toward the area of Kishwaukee Street and Harrison Avenue.

The next-highest concentration of 1,2-DCE outside the Area 7 plume was in the Area 8 plume, where IW23 had 390 ppb. One downgradient well, IW21, had 8 ppb of cis-1,2-DCE.

Elevated concentrations of 1,2-DCE were reported for the area defined above as the Area 9/10 plume. Concentrations reached 210 ppb (at MW124) in this plume. The 1,2-DCE plume in Area 9 appears to have similar extent as the plume defined for TCA.

Slightly elevated concentrations of 1,2-DCE were present in the final three areas that showed contamination by TCA (Area 4, Area 16, and Area 18). Peak concentrations of this compound were between 25 and 50 ppb in these areas.

1,1-DCA and 1,1-DCE

The compounds 1,1-dichloroethane (1,1-DCA) and 1,1-dichloroethene (1,1-DCE) were the third and fourth most-frequently detected compounds in Phase II groundwater samples. Their widespread distribution probably reflects their origin as common degradation products of TCA (Olsen and Davis, 1990; also see subsection 4.9). The compound 1,1-DCA commonly forms through the biological degradation of TCA in an anaerobic environment, while 1,1-DCE has been reported to form primarily by abiotic degradation (in either aerobic or anaerobic environments) of TCA; the TCE to 1,1-DCE transformation is a minor pathway. These two compounds generally follow the distribution of other chlorinated organic contaminants discussed above, with elevated concentrations being found in the contaminant plume located downgradient from Area 7 (up to 330 ppb for 1,1-DCA, at MW103C, and 180 ppb for 1,1-DCE, at MW135; see Figure 4-30 for locations). Concentrations generally decline in the downgradient direction.

Elevated concentrations of 1,1-DCA downgradient from MW20 strongly indicate that an additional source of chlorinated VOC contamination affects groundwater downgradient from MW20. Concentrations of 1,1-DCA are relatively low at MW127, MW20, and MW41 (15 to 52 ppb); downgradient from MW20, concentrations of 1,1-DCA at MW125, MW126A and B, and MW124 are considerably higher (94 to 2,100 ppb). These concentrations are too high to have originated from the Area 7 or Area 11 plumes located approximately upgradient from MW20. These elevated concentrations are at the same locations noted to have contained elevated concentrations of other VOCs, which were named the Area 9/10 plume.

Throughout the Area 7 plume and most other groundwater contaminant plumes, 1,1-DCE is present at concentrations consistently less than those of its likely parent compound, TCA. However, in several wells near MW20 (within the Area 9/10 plume), located approximately downgradient from Area 11, the concentration of 1,1-DCA is considerably greater than that of TCA (at MW127, MW20, MW125, MW126A and B, and MW41). This pattern, also noted in the Phase I report (CDM, 1992), appears to indicate that TCA has undergone additional degradation

in the area of these wells. Such a degradation process may be facilitated by the presence in this area of an additional source of organic carbon (benzene, toluene, ethylbenzene, and xylene [BTEX]) from potential source Area 11 located about 1,000 to 2,000 feet upgradient of these wells, as well as low dissolved oxygen contents (which are likely, based on the persistence of the easily-degradable BTEX compounds in the wells in question; see discussion below on BTEX compounds). As noted above, the degradation of TCA to 1,1-DCA proceeds most readily in an anaerobic environment, and the addition of the extensive source of BTEX and other related petroleum compounds from Area 11 appear to have created the requisite conditions.

The low concentrations of 1,1-DCA at MW127, MW20, and MW41 probably formed through the degradation of TCA in the trailing parts of the Area 7 and Area 11 plumes just upgradient, in the area where the high BTEX compounds from Area 11 encounter the Area 7 and Area 11 plumes. The strongly elevated concentrations of 1,1-DCA at MW125, MW126A, and MW126B also probably formed through degradation (note the high BTEX concentrations in these wells), but higher concentrations probably result from the addition of TCA from a nearby contaminant source area; the TCA subsequently degrades in this favorable subsurface environment. As discussed under TCA, the suspected source area is probably located north of, and side-gradient to, MW20, near the boundary between Areas 9 and 10.

Another piece of evidence favoring the biodegradation hypothesis near MW20 is the fact that the concentration of 1,1-DCE is low relative to 1,1-DCA. As 1,1-DCE results not from the biodegradation of TCA, but as a product of abiotic degradation of TCA, it would not be expected to be present at elevated levels where no new TCA source has affected the aquifer, such as at MW127, MW20, and MW41. These wells are upgradient or side-gradient to the suspected TCA source area near the boundary between Areas 9 and 10, but are downgradient from and affected by the elevated BTEX compounds from Area 11. It is therefore consistent with the idea of biodegradation that the concentrations of 1,1-DCA but not 1,1-DCE are at elevated levels in MW127, MW20, and MW41 relative to wells upgradient.

In other areas, 1,1-DCA and 1,1-DCE generally follow the distribution of TCA, as might be expected based on their likely origin through the degradation of TCA. These daughter compounds were both detected in the Area 4, Area 8, Area 9/10, and Area 15 contaminant plumes, as was TCA. Of the two compounds, only 1,1-DCE was detected in the small Area 18 plume, which showed low concentrations of TCA. Neither 1,1-DCA nor 1,1-DCE was detected in the Area 11 plume, but this was probably due to elevated detection limits (500 ppb) in the single sample (IW11) containing TCA in Area 11. Neither 1,1-DCA nor 1,1-DCE was detected in MW1 or MW5 collected from the northern part of the study area (Area 17 plume); TCE was detected and TCA not detected in these samples. Such a pattern is to be expected at this well nest, because 1,1-DCA and 1,1-DCE are expected to follow TCA, based on their likely derivation through degradation of TCA and not from TCE.

Vinyl Chloride

Vinyl chloride was detected at ten of the 120 monitoring wells sampled in Phase II; in seven of these wells the concentration was above the MCL for vinyl chloride of 2 ppb. Concentrations of vinyl chloride ranged up to 75 ppb at MW134A; detections were reported from wells in the Area

7, Area 9, and Area 13 contaminant plumes. The detections of vinyl chloride were limited primarily to wells where degradation products were present in especially high proportions (particularly 1,1-DCA, 1,2-DCE, and chloroethane). The highest vinyl chloride concentrations (above 10 ppb) were found in wells where BTEX compounds were also present (at MW134A, IW3, MW41, and MW126B). Though vinyl chloride is produced in large quantities, its existence in the study area is likely attributable to biodegradation. These patterns are in line with the common origin of vinyl chloride as a result of the biodegradation of 1,1-DCE or 1,2-DCE (Vogel et al., 1987), which occurs in anaerobic systems. The presence of BTEX compounds at or just upgradient from these wells denotes a low-oxygen, possibly anaerobic, environment.

Vinyl chloride does not persist far downgradient from wells where it was detected. This may be due to the resumption of oxygenated conditions in the aquifer downgradient from these wells, which is indicated by the depletion of the BTEX compounds; vinyl chloride has been shown to be susceptible to biodegradation in an aerobic environment (Hartmans et al., 1985). The resumption of oxygenating conditions in the aquifer makes sense for the study area, where the water table is relatively shallow and subsurface materials are relatively permeable, glacially-derived deposits that allow easy infiltration of oxygen-bearing precipitation water. The pattern of vinyl chloride distribution is similar to BTEX compounds in that both become attenuated not far downgradient from source areas. Based on the susceptibility of both sets of compounds to aerobic biodegradation (see discussion on BTEX compounds below), the relatively rapid attenuation of these compounds is probably explained by biodegradation. Alternatively, the lack of persistence of vinyl chloride may be due to its high vapor pressure (2,600 mm Hg), resulting in losses through volatilization.

Other Chlorinated Compounds

As summarized in Table 4-8, the following additional chlorinated compounds were detected at between one and 17 of the 120 monitoring wells sampled in Phase II: chloroform, 1,2-dichloroethane, methylene chloride, chloroethane, 1,1,2-trichloroethane, 1,2-dichloropropane, bromochloromethane. Of these compounds, MCLs exist and were exceeded for 1,2-dichloroethane, methylene chloride, 1,1,2-trichloroethane, and 1,2-dichloropropane.

Among the compounds listed above, the greatest number of exceedances of MCLs was reported for methylene chloride, detected in six Phase II-sampled wells at concentrations above its MCL of 5 ppb. Methylene chloride is used in paint removers, solvent degreasing, plastics processing, as a blowing agent in foams, in solvent extraction, and as a solvent for cellulose acetate. Two of the wells with methylene chloride detections were in the Area 13 plume, where IW1 and IW3 contained 2,700 and 10 ppb; IW23 in the Area 8 plume contained 390 ppb. Other detections above the MCL were at MW102C (55 ppb) in the Area 7 plume, MW102A (23 ppb) in the perched aquifer, and MW130 (8 ppb) in the Area 4 plume. Detections of methylene chloride below the MCL were noted for wells in the Area 9, Area 13, and Area 8 plumes.

The compound 1,2-dichloroethane (1,2-DCA) was detected in six Phase II-sampled wells at concentrations above its MCL of 5 ppb; the peak concentration was 26 ppb (MW105B). Three of these detections were in the Area 7 plume (at MW105B, MW105A, and MW134B), two were in the Area 9/10 plume (at MW126B and MW125), and one in the Area 13 plume (at IW3).

Detections of 1,2-DCA below the MCL were reported for wells in the Area 7, Area 9, and Area 13 plumes. This compound has uses as a vinyl chloride solvent; a lead scavenger in antiknock unleaded gasoline; in paint, varnish, and finish removers; metal degreasers; soaps and scouring compounds; wetting and penetrating agents; organic synthesis; ore flotation; tobacco flavoring; and as a soil and foodstuff fumigant. Neither methylene chloride nor 1,2-DCA are known to be products of degradation; therefore, their presence in the study area probably reflects initial disposal of products containing these compounds, rather than originating through degradation.

The compound 1,1,2-trichloroethane was detected at two wells sampled in Phase II, both located in the Area 9/10 plume. The concentration of 60 ppb reported from MW124 exceeds the MCL of 5 ppb. This compound is used as a solvents for fats, oils, waxes, resins, and other products; and in organic synthesis.

The single detection of 1,2-dichloropropane was reported from well IW3 in the Area 13 plume; the concentration of 7 ppb at that well exceeds the MCL of 5 ppb. This compound has a wide variety of uses, including as an intermediate for PCE and carbon tetrachloride; a lead scavenger for antiknock fluids; a solvent for fats, oils, waxes, gums, and resins; in solvent mixtures for cellulose esters and ethers; scouring compounds; spotting agents; metal degreasing agents; and as a soil fumigant for nematodes.

Though detected in only eight wells sampled in Phase II, chloroethane was present in concentrations ranging up to 500 ppb. The seven highest detections were located in wells in the Area 9/10 plume. As noted above, wells in this plume have proportionally high concentrations of the likely biodegradation daughter products 1,1-DCA and vinyl chloride. Chloroethane can form through the biodegradation of either 1,1-DCA or cis-1,2-DCE, which can occur under anaerobic conditions (Vogel et al., 1987). As discussed above, 1,1-DCA is abundant in the Area 9/10 plume, and the requisite anaerobic or at least low-oxygen conditions for degradation of 1,1-DCA to chloroethane are likely provided by high BTEX concentrations originating from Area 11 or other unknown sources just upgradient from the Area 9/10 plume. Vogel and McCarty (1987) found in their research that the rate of the transformation of 1,1-DCA to chloroethane is slower than the transformation of TCA to 1,1-DCA. The low concentration of chloroethane relative to 1,1-DCA throughout the study area is consistent with these findings. In addition, the association of chloroethane in areas where other biodegradation products are present, particularly where these concentrations are combined with low oxygen content in groundwater, supports the activity of biodegradation in producing chloroethane concentrations in groundwater.

Chloroform was detected in 17 of the 120 wells sampled in Phase II. Of the wells with detections, the highest concentrations and greatest number of detections were reported from Area 7: ten wells in the Area 7 plume had chloroform detections, and concentrations ranged up to 72 ppb at MW101C. The other detections of chloroform were scattered among wells in the Areas 9, 13, 18, and 19 plumes, where concentrations ranged from 0.4 to 13 ppb. There is no MCL for chloroform specifically; however, an MCL of 100 ppb applies to the total of trihalomethanes as a group, of which chloroform is one compound. No other trihalomethanes were reported from groundwater samples in the study area, and this MCL was therefore not exceeded. Chloroform has uses in fluorocarbon refrigerants, fluorocarbon plastics, analytical

chemistry, insecticides, and anesthetics; as a solvent for natural products and a soil fumigant; in the preparation of chlorodifluoromethane; and in cleaning electronic circuit boards.

Benzene, Toluene, Ethylbenzene, and Xylene

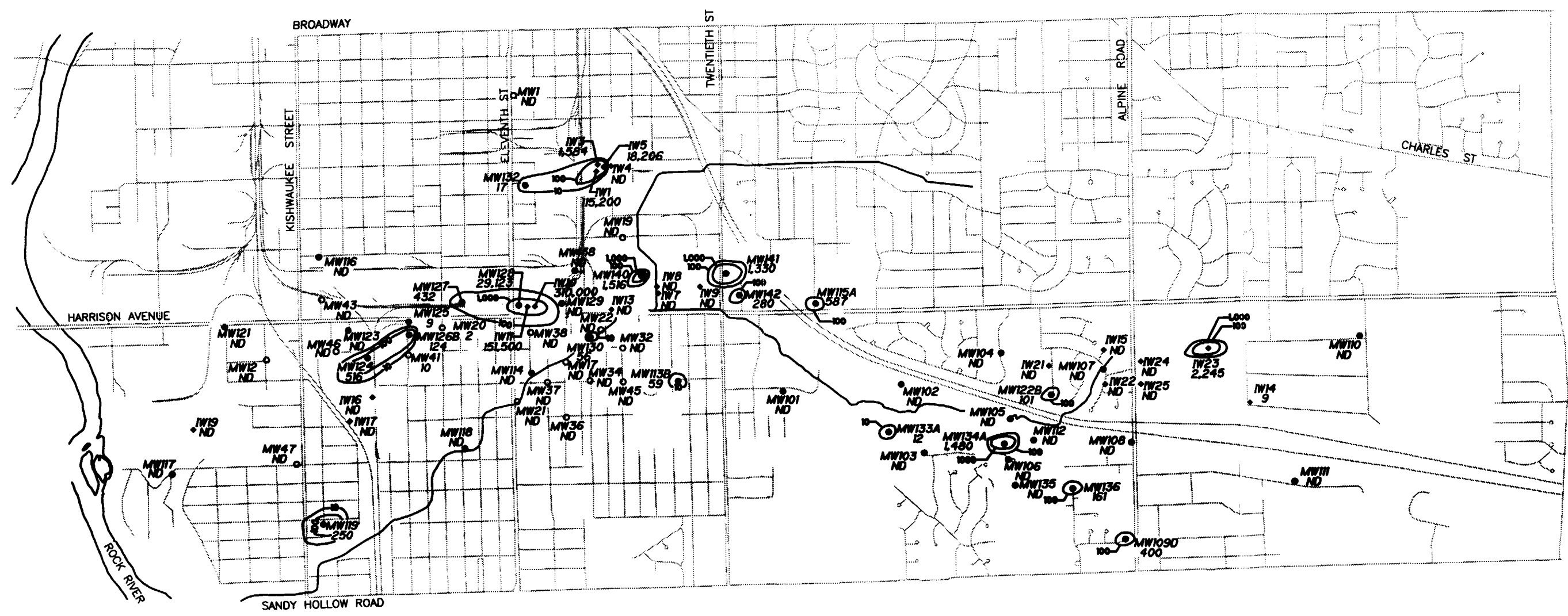
Benzene, toluene, ethylbenzene, and xylene (BTEX) compounds were detected in groundwater from eight, 28, 16, and 23 wells, respectively, of the 120 wells sampled in Phase II (see Table 4-8). Detections above the MCL for these compounds were reported for five, eight, four, and two of these wells. In general, detections of these compounds were found in the same or in nearby samples. For example, while toluene was the most frequently detected compound of the group, most detections of the other BTEX compounds were found in samples that also had detections of toluene. Likely sources of these components from spillage of varnishes, solvents, and paint removers. Gasoline is also a possible source, however relatively low concentrations of benzene compared to ETX compounds does not support this. Based on their similar distribution pattern as well as their similar properties, BTEX compounds are discussed together.

Detections of BTEX compounds were noted at or near many of the potential source areas that have elevated chlorinated VOCs. However, BTEX compounds have their own distribution patterns that differ from those of the chlorinated VOCs in two important ways: 1) though BTEX compound concentrations may be extremely high (up to 310 ppm) at specific locations, these compounds are attenuated rapidly in the subsurface and do not form extensive plumes; and 2) some BTEX compound detections in groundwater were found in wells where chlorinated VOCs were not detected. Figure 4-38 shows the maximum BTEX concentration at the Phase II sampling locations.

The highest and most extensive concentrations of BTEX compounds in groundwater were found in Area 11. IW10 contained 310,000 ppb of toluene (other compounds were not detected at the detection limit of 20,000 ppb), while the total concentration of BTEX compounds was 149,800 and 29,123 ppb at nearby wells IW11 and MW128, respectively. The concentration of toluene in IW10 is about 60% of its solubility of 515 ppm; along with the results of subsurface soil sampling in Area 11, this indicates that a light non-aqueous phase liquid (LNAPL) may be present in this area. BTEX compound concentrations downgradient from the Area 11 high contamination zone are about three orders of magnitude lower than in the high contamination zone, and thus probably represent dissolved-phase contamination by BTEX compounds. All wells between MW127 and MW124 (also including MW20, MW125, MW126A and B, and MW41) contained detectable BTEX compounds, at concentrations ranging from 2 to 516 ppb total BTEX. No detections of BTEX compounds were noted downgradient from MW124. As a result, the total length of the BTEX-contaminated area extends from Area 11 to the middle of the Area 9/10 plume, for a total distance of about 4,000 feet.

The second-highest and second-most extensive detections of BTEX compounds were noted in samples from the Area 13 plume. IW1 contained 115,200 ppb of total BTEX compounds, while IW5, IW3, and MW132 had BTEX concentrations ranging from 17,700 to 17 ppb. The extent of this contaminated zone is not known, but BTEX contaminants do not extend to the vicinity of the Area 16 plume, located about one mile downgradient.

M. KUZEL, NMW-CHI
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11/21/94 16:39:15
FIG 4-38
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LEGEND:

- MW12 ISWS MONITORING WELL
- MW101 CDM/EPA MONITORING WELL OR WELL NEST; LETTER SUFFIX INDICATES SPECIFIC WELL OF A WELL NEST
- IW14 INDUSTRIAL MONITORING WELL OR SUPPLY WELL
- 100 --- TOTAL BETX * CONTOUR (ug/L), DASHED WHERE INFERRED
- ND CONCENTRATION BELOW DETECTION LIMIT
- * SUM OF BENZENE, ETHYLBENZENE, TOLUENE AND XYLENE

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GROUNDWATER CONTAMINATION STUDY
BETX CONCENTRATIONS IN
PHASE II GROUNDWATER, 1993

Several other areas identified as chlorinated VOC contaminant plumes or areas of contamination also contain detectable concentrations of BTEX compounds. These areas, followed by their peak concentration of total BTEX compounds, are: the Area 8 plume (2,200 ppb at IW23); at well MW140 located downgradient of Suntec Industries (1,516 ppb); the Area 7 plume (1,480 ppb at MW134A); and the Area 4 plume (MW130 at 56 ppb). Of these four areas, the Area 7 plume had three other wells with detections, at concentrations between five and 29 ppb of total BTEX compounds. The other three areas had only a single well with detections of BTEX compounds. As a result, none of these areas has extensive or concentrated plumes of BTEX compounds.

The remaining detections of BTEX compounds were from wells which contained very low (less than 10 ppb) to undetectable concentrations of chlorinated VOCs. Detections of BTEX compounds were reported for wells MW141, MW115A, and MW142, located near the Gordon-Bartels facility; total BTEX compound concentrations ranged from 280 to 1,330 ppb in these wells. At the Gordon-Bartels facility, toluene, xylene, and ethylbenzene were detected at ppm levels in soils located near tanks that were recently removed and found to have leaking lines. The groundwater BTEX concentrations do not appear to constitute an extensive plume, as wells IW9 and MW19, located roughly downgradient, did not contain detectable BTEX compounds. The remaining wells with detections of BTEX compounds are not related to known source areas, though candidate source areas exist for some. BTEX contamination at MW109D and MW136 (total BTEX compounds are present at 400 and 161 ppb, respectively) may or may not be parts of the same contaminated zone, which could be emanating from upgradient areas that were not studied in detail. MW119 contained toluene at 250 ppb; a number of small to medium-sized facilities exist south, southwest, and west of this location. Finally, detections of total BTEX compounds at MW122B, MW113B, MW133A, and IW14 range from 101 to 9 ppb. There are no other BTEX detections in the nearest groundwater samples upgradient or downgradient from each of these wells. As a result, potential sources of these BTEX detections are not known; in addition, defineable contaminant plumes do not exist surrounding any of these wells.

The overall pattern of distribution of BTEX compounds is that they are present in most of the known source areas or potential source areas. However, concentrations decline rapidly away from most of these areas, to the extent that BTEX contaminant plumes are not apparent, or are short (less than 2,000 feet) and of low concentration. The exception is the area extending from Area 11 to the middle of the Area 9/10 plume (which was defined for chlorinated VOCs), where contamination by BTEX compounds encompasses an area of highly contaminated soils and a dissolved-phase BTEX contaminant plume.

The relatively rapid attenuation of BTEX compounds in groundwater (compared to chlorinated VOCs, which have extensive plumes) is most likely due to the susceptibility of these compounds to biodegradation in oxygen-bearing groundwaters or soils. Chiang and others (1989) concluded from studies of a sandy aquifer that BTX (benzene, toluene, and xylene) removal was directly related to dissolved oxygen (DO) concentration, with BTX being absent when DO concentrations were greater than 0.9 mg/L. As the equilibrium DO content of fresh water at 10°C is about 11 mg/L and shallow groundwaters are commonly in the range of 2 to 5 mg/L of DO (Hem, 1985), it is expected that the shallow groundwaters in the study area contain sufficient DO to accomplish rapid degradation of BTX. Degradation is probably slow only in areas of LNAPL, where the access of DO is likely to be minimal; in these areas, volatilization probably is an

important process in causing BTEX losses from the subsurface. Rapid biodegradation of BTEX compounds in the dissolved phase would account for the observed rapid attenuation of these compounds in groundwaters downgradient from high-concentration detections of BTEX.

Ketones

Acetone, 2-butanone, 4-methyl-2-pentanone, and 2-hexanone are ketones that were detected in three, nine, five, and one well(s), respectively. These compounds have numerous uses, including as solvents for paints, varnishes, and lacquers, as cleaning fluids, and in cements, sealants, and adhesives. The highest concentrations of these compounds were found in the Area 13 and Area 11 plumes. In the Area 13 vicinity, concentrations of total ketones were 5,815 and 27,800 ppb, at IW3 and IW1, respectively; at well MW132 roughly downgradient, the concentration of total ketones was 30 ppb. The second major detection of ketones was in Area 11 at well MW128, where total ketones were present at 4,040 ppb; elevated concentrations may also exist at nearby Area 11 wells IW10 and IW11, but may have been missed due to the elevated detection limits at these wells. Based on existing data in both the Acme area and Area 11, ketones do not appear to persist in the aquifer to form an extensive plume.

In order of descending concentration, other detections of ketones were reported from wells MW136, IW14, MW126B, MW113B, MW138, and MW111A, at total ketone concentrations of 66 to 7 ppb. Most of these wells also had detections of BTEX compounds; also similar to BTEX, these ketone detections are not associated with detections in the nearby wells in upgradient or downgradient directions. The overall patterns of the distribution of ketones are similar to BTEX compounds in showing locally high concentrations at Area 13 and Area 11, and relatively rapid attenuation of concentrations downgradient; these patterns suggest similar methods of contaminant attenuation through biodegradation or possibly volatilization. The ketones are susceptible to biodegradation in both aerobic and anaerobic environments (Howard, 1990).

Extractables, Pesticides, and PCBs

The results of Phase I groundwater sampling established that extractables, pesticides, and PCBs are not present at elevated concentrations in groundwater in the study area, except at locations relatively near likely contaminant source areas. As a result, groundwater samples were analyzed for these constituents only in 25 selected wells that were newly installed in Phase II.

The compound bis(2-ethylhexyl)phthalate was the most commonly detected of the extractables, pesticides, and PCBs, being detected in nine of the 25 wells analyzed for these compounds. This compound was also detected at the highest concentration of these compounds, ranging up to 190 ppb (at MW142); bis(2-ethylhexyl)phthalate was also the only compound in these groups to exceed its MCL of 6 ppb (for total phthalates), which occurred in four of the wells sampled. The three highest concentrations of bis(2-ethylhexyl)phthalate were found in MW142 (190 ppb), MW127 (14 ppb), and MW141 (12 ppb). These wells are located relatively near suspected source areas at Gordon-Bartels (MW142 and MW141) and Area 11 (MW127), and had elevated concentrations of several VOCs, particularly toluene (280 to 1,300 ppb). The other six detections of bis(2-ethylhexyl)phthalate were less than 8 ppb; four of these detections were from wells which had relatively low concentrations of total VOCs (less than 250 ppb of total VOCs).

Conversely, this compound was not detected in most of the wells that had the highest levels of other contaminants (greater than 1,000 ppb of total VOCs), including MW124, 128, 130, 133B, 134A, and 135. These patterns of distribution for bis(2-ethylhexyl)phthalate suggest that the compound is not migrating in groundwater across large distances from suspected source areas. In addition, low concentrations of the compound (less than 10 ppb) are not correlated with groundwater contamination by other compounds; such concentrations are most likely the result of laboratory or sampling contamination, a common effect for bis(2-ethylhexyl)phthalate.

After bis(2-ethylhexyl)phthalate, the highest abundances of extractable, pesticide, or PCB compounds in Phase II groundwater samples were reported for the phenolic compounds 2-methylphenol, 4-methylphenol, and 2,4-dimethylphenol. These compounds were present in five, two, and two wells, respectively, and at the peak concentrations of 100 ppb (MW128), 88 ppb (MW134A), and 54 ppb (MW128), respectively. All three compounds were present at MW128 and MW134A, which thus accounted for six of the nine total detections of these compounds. The three additional detections of phenolic compounds were for 2-methylphenol; this compound was reported at MW140 (14 ppb), MW141 (3 ppb), and MW142 (3 ppb). The five wells with detections of phenolic compounds are all located within about 750 feet of suspected source areas at Area 7, Area 11, Area 19, and Gordon Bartels Company. The distribution patterns for the phenolic compounds are consistent with limited migration of low concentrations of these compounds in groundwater in the study area; discernible plumes do not exist.

Naphthalene and 2-methylnaphthalene were each detected in the same three Phase II-sampled wells: MW134A, MW128, and MW135. The peak concentration of naphthalene was 43 ppb (at MW134A), while the peak concentration for 2-methylnaphthalene was 5 ppb (at MW128). These two compounds are polycyclic aromatic hydrocarbons (PAHs) that are common constituents of petroleum products, and are thus commonly present in waste oils. The three wells that showed detections of these compounds are located within, or up to 100 feet away from, source Areas 7 and 11. The low-level detections in these wells, coupled with the lack of downgradient detections, indicate that naphthalene and 2-methylnaphthalene are not migrating significantly in groundwater in the study area.

The compound 1,2-dichlorobenzene was detected in two wells sampled in Phase II: in MW134A (at 28 ppb) and in MW128 (at 10 ppb). These wells were also the primary locations of detectable concentrations of phenolic compounds and PAHs. Similar to these compounds, 1,2-dichlorobenzene appears to migrate in groundwater only to a very limited extent (less than 200 feet from source areas), based on low-concentration detections in these wells, and a lack of downgradient detections.

The final extractable compounds detected in Phase II groundwater samples were di-n-butylphthalate and diethylphthalate, which were detected at two wells and one well, respectively, at concentrations ranging from 0.6 to 1 ppb.

No pesticides or PCBs were detected in any Phase II groundwater samples.

Inorganic Constituents

The results of Phase I groundwater sampling established that inorganic constituents are not widely distributed at elevated levels in the study areas. As a result, groundwater samples were analyzed for these constituents only in 25 monitoring wells that were installed in Phase II. The results of Phase II groundwater sampling are summarized in Table 4-9; included in this table are inorganic constituents for which one or more samples exceeded 50% of the primary or secondary MCL. Antimony and thallium were the only two inorganics for which a primary MCL was exceeded. The concentration of antimony at MW124 was 10.2 ppb, slightly above the MCL 6 ppb. This concentration is well below the Contract Required Detection Limit (CRDL) of 60 ppb. No other detections of antimony were reported for Phase II samples, which suggests that extensive migration of this element is not occurring in the study area.

The concentration of thallium exceeded the primary MCL at two of the 25 wells sampled and analyzed for inorganics. MW119 (2.4 ppb) and MW136 (2.2 ppb) slightly exceeded the MCL of 2 ppb. These concentrations are just above the instrument detection limit (generally 1.6 ppb), and considerably below the CRDL of 10 ppb. Based on the low concentrations of the thallium detections and the fact that only four samples had reported detections of this metal, extensive migration of thallium does not appear to be proceeding in the study area. In addition, it is not known whether the detections of thallium are simply background concentrations characteristic of local groundwaters.

Nickel and arsenic were detected at concentrations of greater than 50 % of their respective MCLs at one monitoring well each. Nickel was detected at 73.2 ppb in MW142 (the MCL for nickel is 100 ppb); the next-highest detection of nickel was 27.6 ppb at MW141 located nearby, while other detections were less than 20 ppb. As these two wells are located close to a potential source area for ETX compounds, these detections of nickel may reflect transport from that source. However, extensive migration of nickel in groundwater in the study area is not likely, and no downgradient impacts have been identified.

Arsenic was detected at 29.1 ppb in MW134A; the next-highest detected concentration was 8.2 ppb at MW128. These detections are located downgradient from nearby VOC source areas, and probably signify localized transport of arsenic in groundwater from source areas. As other wells contained no more than 6.3 ppb of arsenic, any extensive migration of arsenic in groundwater in the study area is at concentrations considerably less than the MCL.

Cyanide was detected at one monitoring well (MW134B) located adjacent to the Area 7 source, at a concentration of 59.4 ppb (considerably below the MCL of 200 ppb). Migration of cyanide from the Area 7 source in groundwater is only localized and at low concentrations; this is based on the absence of detections of the compound in downgradient wells in Area 7 (at well nest MW133), as well as the lack of detections in other wells immediately downgradient from Area 7 (at MW134A, MW134C, and MW105).

Manganese, aluminum, and iron were detected at concentrations above their respective secondary MCLs in 13, six, and five Phase II-sampled monitoring wells, respectively. The highest concentrations of manganese were found at MW128, MW126B, and MW126A (at 1,410,

Table 4 - 9: Groundwater Inorganic Constituents - Range and Frequency of Detection

Constituent	MCL, ppb	Unconsolidated and Bedrock Aquifers		
		Range of Phase II Samples With Detections, ppb	Proportion of Phase II Samples With Detections	Proportion of Samples at or Exceeding MCL
Aluminum	50-200	16.5 - 1730	24 / 25 (96%)	6 / 25 (24%)
Antimony	6	10.2 - 10.2	1 / 25 (4%)	1 / 25 (4%)
Arsenic	50	1.4 - 29.1	12 / 25 (48%)	0 / 25 (0%)
Barium	2000	21.6 - 214	25 / 25 (100%)	0 / 25 (0%)
Beryllium	4	None	0 / 25 (0%)	0 / 25 (0%)
Cadmium	5	1 - 1	1 / 25 (4%)	0 / 25 (0%)
Calcium	--	52200 - 127000	25 / 25 (100%)	N/A
Chromium	100	2.2 - 19.3	5 / 25 (20%)	0 / 25 (0%)
Cobalt	--	4.4 - 29.4	3 / 25 (12%)	N/A
Copper	1300	2.6 - 12.3	15 / 25 (60%)	0 / 25 (0%)
Iron	300	20.4 - 4070	18 / 25 (72%)	5 / 25 (20%)
Lead	15	2.6 - 5.6	5 / 25 (20%)	0 / 25 (0%)
Magnesium	--	20900 - 49800	25 / 25 (100%)	N/A
Manganese	50	2.7 - 1410	25 / 25 (100%)	13 / 25 (52%)
Mercury	2	0.2 - 0.2	1 / 25 (4%)	0 / 25 (0%)
Nickel	100	4 - 73.2	11 / 25 (44%)	0 / 25 (0%)
Potassium	--	822 - 5690	25 / 25 (100%)	N/A
Selenium	50	3.2 - 3.6	2 / 25 (8%)	0 / 25 (0%)
Silver	100	None	0 / 25 (0%)	0 / 25 (0%)
Sodium	--	7380 - 292000	25 / 25 (100%)	N/A
Thallium	2	1.6 - 2.4	4 / 25 (16%)	2 / 25 (8%)
Vanadium	--	2.8 - 6.5	5 / 25 (20%)	N/A
Zinc	5000	4.8 - 25.3	10 / 25 (40%)	0 / 25 (0%)
Cyanide	200	59.4 - 59.4	1 / 25 (4%)	0 / 25 (0%)

Notes:

MCLs listed for aluminum, iron, manganese, silver, and zinc are secondary values that are recommended but not promulgated

600, and 596 ppb, respectively), while all other wells contained less than 300 ppb. These wells are located near two known or suspected VOC source areas, and suggest limited migration of manganese in groundwater in the study area. Iron displayed an even more skewed distribution than manganese: the five wells above the secondary MCL contained between 661 and 4,070 ppb of iron, while the other 20 wells contained less than 250 ppb, with most of these (18 wells) having less than 100 ppb. Three of the five iron detections above the secondary MCL were downgradient of known sources of VOCs to groundwater (MW134A, MW132, and MW134C), and probably represent limited transport of iron in groundwater. Though manganese and iron are naturally-occurring metallic constituents of groundwater, the elevated concentrations at certain wells located near VOC source areas are high enough to conclude that limited migration of these components is taking place in study area groundwater.

Instances of aluminum detections above the secondary MCL (which ranges from 50 to 200 ppb, based on local conditions; Jan. 30, 1991 Federal Register, p. 3573) were found at six wells in the western portion of the study area. The wells with these elevated concentrations of aluminum are not well correlated with elevated concentrations of VOCs or metals; as a result, the sources and directions of transport of aluminum are not clear in the study area.

In summary, for inorganic constituents that have a primary MCL (mainly heavy metals), four were detected in the study area at concentrations greater than 50 % of their respective MCLs. Of these, none appear to be migrating more than short distances from the VOC source areas. Several metals with secondary MCLs (non-health-based) have a somewhat wider distribution at concentrations above MCLs, with the highest concentrations generally located near the VOC source areas.

4.9 Fate and Transport of Groundwater Contaminants

VOCs are the primary groundwater contaminants in the contaminated shallow aquifers in the study area, including chlorinated VOCs, BETX compounds, and ketones. Other contaminants are found only locally, and then primarily only in soils, including certain PAHs, pesticides, PCBs, heavy metals, and cyanide. Of these, all except for cyanide were either undetected in groundwater, or in the case of heavy metals, detected at concentrations likely to represent natural concentrations in the groundwater. Cyanide was detected in one Phase II-sampled well at a concentration of 59.4 ppb; this well is located adjacent to the Area 7 source. These patterns of contaminant distribution in soils and groundwater show that PAHs, pesticides, PCBs, heavy metals, and cyanide are nearly immobile in the subsurface environment, and are therefore not contaminants of concern for groundwater. Therefore, most of the discussion in this subsection will deal with VOC contaminants in soils and groundwater.

4.9.1 Potential Source Area Characteristics

Anomalous concentrations of the target VOC compounds (TCA, TCE, and PCE) were identified in soil gas in all 12 of the potential source areas that were sampled for soil gas (also see subsection 4.2). However, some of the areas with low to moderately elevated VOCs likely have those concentrations as a result of either 1) localized or low-concentration occurrences of VOCs

in soils; or 2) contaminant volatilization from shallow contaminated groundwater that originated upgradient from the source in question. In such cases (Areas 1, 2, 3, 5, and 14), the potential source areas do not appear to currently effect the groundwater (see subsection 4.10). The complete picture is not clear in Areas 9 and 10 because access was not acquired to the entire portion of these areas; based on groundwater and soil gas results, it is possible that contaminant source areas may exist near the southern boundary between these two potential source areas. Area 6 was not investigated in Phase II, but was eliminated as a likely contaminant source area a short time before Phase II field work, owing primarily to newly-acquired aerial photo evidence. Area 8 was not sampled for soil gas or subsurface soils, but is considered a likely source area; this conclusion is based on evidence from on-site, upgradient, and downgradient monitoring wells; the occurrence of at least one solvent spill; and the existence of high TCA and toluene concentrations on-site.

The other potential source areas not listed above (Areas 4, 7, 11, 12, and 13) are likely to have affected downgradient groundwater quality, based on information gathered in this RI. Phase II characterization of these likely source areas was accomplished through soil gas and subsurface soil sampling (no subsurface soil sampling in Area 13), and in the case of Area 7, test pit excavation and sampling. Of the likely source areas, the results of subsurface soil sampling show that high VOC concentrations exist near the top of the saturated zone in Areas 4, 7, 11, and 12. Area 13 likely falls in the same category, based on the soil gas and groundwater sampling results. The existing information is insufficient to characterize subsurface conditions in the area.

Non-aqueous phase liquids (NAPLs) comprised of both dense and light NAPL compounds, may be present in each of the potential source areas mentioned above. This Phase II study was not designed to investigate or characterize NAPL zones. It will be important in future source area investigations to include NAPL characterization as an objective. The significance of identifying contaminant sources as a NAPL is that NAPLs will not mix appreciably with water; owing to the limited solubility and volatility of the constituent VOCs. NAPLs also tend to remain at or near their original location below the disposal site for an extended period of time. As a result, any NAPLs existing in the vicinity of the water table in source areas mentioned above pose a continuing contaminant source to groundwater through the slow dissolution of their constituent compounds into infiltrating rainwater and groundwater.

NAPLs are commonly referred to as either dense non-aqueous phase liquids (DNAPLs) or as light non-aqueous phase liquids (LNAPLs). The distinction between LNAPL and DNAPL is based on the specific gravity of the compounds comprising the NAPL. LNAPLs are commonly comprised of compounds which exhibit a specific gravity less than 1.0, i.e. non-chlorinated VOCs such as benzene, toluene, ethylbenzene, and xylene. DNAPLs are comprised of compounds which exhibit a specific gravity greater than 1.0, such as polychlorinated biphenyls (PCBs) and halogenated solvents (i.e., PCE, TCE, TCA, DCE).

Given that the specific gravity of water is 1.0, LNAPLs which have migrated through the unsaturated zone have a tendency to float and/or remain in the uppermost portions of an aquifer. LNAPLs tend to form relatively continuous, compact masses near the water table. This is important when considering NAPL characterization and remediation since such bodies are easier to define the limits of as well as to clean up.

NAPL masses comprised predominantly of DNAPL compounds which come in contact with an aquifer will tend to migrate downward within an aquifer system. DNAPL compounds may also be found at the water table interface which appeared to be the case in the potential source areas mentioned above. Whether or not a DNAPL will migrate downward into an aquifer is strongly dependent upon the thickness and composition of the DNAPL mass accumulated on the water table and the pore size of fracture aperture of the aquifer media at the water table (USEPA, 1993d). Once in an aquifer system, the vertical and horizontal location of a DNAPL can be difficult to locate and define. DNAPL occurrences commonly feature hard-to-find narrow stringers and finger-like projections of contaminants that penetrate far into the saturated zone, and may also comprise pools at variable depths within an aquifer existing on strata of lower permeability. Once in contact with a low permeability strata such as clay, silt, or a bedrock interface, the potential for downward migration through such strata depends upon the density of the DNAPL mass, the pore radius or fracture aperture of the strata, the thickness of the DNAPL mass resting on the top of the strata, the capillary pressure gradients within the strata, and hydraulic pressure differentials between the aquifer and potential aquitard/aquiclude. In a heterogeneous geologic medium with multiple aquifers and discontinuous clay/silt layers, DNAPL masses are inherently very difficult to locate and to clean up.

To evaluate whether or not a NAPL mass observed in a suspected source area can be expected to migrate downward into an aquifer, the specific gravities of the various compounds which comprise the NAPL mass should be examined. In Areas 4, 7, and 12, high concentrations of halogenated solvents are present in the NAPL zones; the compounds of this type in greatest abundance (TCA, PCE, TCE, and 1,2-DCE) have specific gravities of 1.28 to 1.63. Significant concentrations of non-chlorinated, aromatic VOCs are also present in Areas 7, 11, and 12; these compounds (xylene, ethylbenzene, and toluene in Areas 7, 11, and 12, with acetone and 2-butanone also present in Area 12) have specific gravities of 0.79 to 0.87. In addition to these compounds on the Target Compound List (TCL), high concentrations of tentatively identified compounds (TICs) were reported from most soils in the high-contamination zones of Areas 4, 7, 11, and 12; these compounds, reported from both the VOC and semivolatile scans, were reported at total concentrations of about two to fifteen times that of the total of the chlorinated (heavy) VOCs. The specified compounds (e.g., decane, nonane) or compound groups (alkanes, aromatics) listed as TICs all have low specific gravities (between 0.7 and 1.0). Combined with the light, non-chlorinated compounds on the TCL, the high concentration of these light TICs probably means that the overall specific gravities are less than or close to 1.0 for the contaminant mass in each of Areas 4, 7, 11, and 12. This explains the presence of DNAPL compounds existing at or in the vicinity of the water table in the potential source areas discussed above.

There was no chemical or physical evidence collected during either the Phase I or Phase II investigation to support the existence of a DNAPL at depth within the aquifer system. However, given the heterogeneity of the system and the inherent difficulty of identifying DNAPLs within an aquifer, the possibility of DNAPLs existing at depth with the aquifer system, especially beneath source areas, should not be eliminated.

Each of the potential source areas where NAPLs are suspected, differs somewhat in the composition of its specific contamination and often contain mixtures of DNAPL and LNAPL components. In each area, the fact that the high contamination is observed in the immediate

vicinity of the water table indicates the bulk of the contaminant mass is comprised of light NAPL compounds. There are significant differences in the composition of the contaminant masses, particularly in the proportion of the various chlorinated VOCs, the proportion of aromatic compounds, and the proportion of degradation daughter products (also see subsection 4.5.1). Considering TCL compounds only, the contaminant mass in Area 4 consists primarily of TCA, with no other TCL compounds being detected (detection limit for Area 4 soils was about 8% of the TCA concentration). Considering TICs, however, the total concentration of alkanes and other hydrocarbons was greater than that of TCA by a factor of at least 20 with aromatics being a very small proportion of this total (about 0.2%). The relative lack of aromatic compounds, which would enhance anaerobic conditions favorable to the degradation of the chlorinated VOCs, may be the reason that daughter products are present at fairly low concentrations (less than 10% that of TCA) in Area 4 subsurface soils and downgradient groundwater (see subsection 4.9.2). The combination of TCA and alkanes in Area 4 is distinctive among the likely contaminant source areas, and may represent a waste solvent contaminated with lubricating oils (which are predominantly high-molecular-weight alkanes, in the C-20 to C-30 range). Considering the information presented above and in Section 4.5.1.2, the highly contaminated zone in Area 4 has dimensions of roughly 50 by 75 feet, with a maximum thickness of at least eight feet.

Within that zone, it is suspected that NAPL exists as residual in the vadose zone. As previously discussed in subsection 4.5.1.2, it is recommended that future source investigations be conducted in a phased manner to confirm and characterize any NAPLs present near the water table or at depth.

The potential NAPL in zones Area 7 differs from that in Area 4 in that it is much more complex in composition: in addition to high concentrations of several chlorinated VOCs (TCA, PCE, TCE, and 1,2-DCE), high levels of the aromatics xylene, ethylbenzene, and toluene are present; among the TICs, even higher concentrations were reported, with both aromatic and alkanes (including cyclic alkanes) represented in both the VOC and semivolatile scans; in addition, anomalous concentrations of PAHs and several metals were reported. The relatively high proportion of aromatic compounds in Area 7 may account for the high proportion of biodegradation daughter products in subsurface soils and downgradient groundwater (see subsection 4.9.2). Based on soil borings and soil gas, the area in Area 7 where NAPL is suspected in the vadose zone appears to be a sinuous zone with dimensions of about 200 by 1,200 feet; the thickness of this zone is between five and 20 feet, but is locally 40 feet. Future source investigations should be conducted in a phased manner, consistent with USEPA guidance for DNAPL site characterization, to confirm and characterize any NAPL zones present in Area 7.

Based on known uses or occurrences of the various compounds in Area 7 (chlorinated VOCs and aromatics are very commonly used as solvents, alkanes are common in lubricating oils, and PAHs and metals commonly accumulate in dirty oils), the complex assemblage of contaminants may represent disposal of a variety of oil-contaminated waste solvents, paint sludges, paint removers, and varnishes. The quantity and variety of the compounds generally used as solvents suggests that disposal originated from a number of different activities at the same facility, or from activities at a number of facilities. Another possibility is suggested by the fact that the primary solvent-type contaminants in Area 7 (chlorinated VOCs and aromatic compounds) are

present across Area 7 in roughly similar proportions (except at the far south, where the PCE-rich contamination may represent an older disposal period), it is possible that the contamination represents disposal from a facility where contaminants from various uses or origins were already mixed.

In Area 11, the area where NAPL contamination is suspected differs from those in the other likely source areas in that chlorinated VOCs are likely present at relatively low concentrations compared to the aromatic compounds. It is important to note that in 8 of the 19 soil samples collected in Area 11, detection limits were elevated by 100 to 1,000 times. Because of these sample dilutions, chlorinated VOCs up to 20,000 ppb in some samples would not have been detected. The most abundant compounds detected are xylene, toluene, and ethylbenzene among compounds on the TCL; similar or lower concentrations of total TICs are also present, including both alkanes and aromatics. Based on the high concentrations of xylene and toluene as well as historical property use (former location of Rockford Varnish), the Area 11 contamination probably originated through leakage or spillage of paint or lacquer solvents, paint thinners, or varnishes. Due to the elevated detection limits, the Area 11 contribution to the total of chlorinated VOCs in downgradient groundwater is unknown. Its high contribution of BETX compounds to the aquifer apparently created a reducing chemical environment that fostered the degradation of certain chlorinated VOCs, resulting in the formation of locally high concentrations of daughter products including vinyl chloride. Based on the soil boring data, there appear to be two separate areas where NAPLs may be present at or above the water table in Area 11, the larger having an estimated areal dimensions of approximately 30 by 120 feet; the thickness of this larger area is generally 5 to 10 feet, and locally as great as 25 feet (see subsection 4.5.1.5).

The suspected NAPL zone in Area 12 is somewhat similar to that in Area 7, based on the wide variety of contaminants present in subsurface soils there. High concentrations (ppm-level) of chlorinated VOCs (PCE, TCE, and TCA), aromatics (xylene, ethylbenzene, and toluene), and ketones (2-butanone and acetone) are present; among TICs, aromatics, alkanes, ketones, and amides are present at total concentrations about twice that of the total of chlorinated VOCs. The Area 12 contamination differs from that of Area 7 in the proportions of compounds: in Area 12 soils PCE and TCE are greater than TCA, and ketones are a major fraction of detected contaminants; the opposite holds in Area 7. Based on the compounds present in Area 12 as well as property uses, it appears that the contamination there originated through the leakage or spilling of a variety of compounds stored in above-ground tanks at the facility. The area of highest contamination where NAPL is suspected in Area 12 has an estimated thickness of about 15 feet and a probable area of no more than 140 square feet (see subsection 4.5.1.6). The recommendations for conduct of future source work made for Areas 4 and 7 would also apply to Area 12.

4.9.2 Processes Affecting Contaminants in and Near Source Areas

Light NAPL Migration

The disposal of the oily, solvent-contaminated light NAPLs to the ground results in downward migration of the liquid mass toward the water table. During this infiltration process, a certain proportion of the NAPL may be left behind after drainage, retained in soil pores through the

force of surface tension; this mass left behind is in residual saturation, and is commonly termed the residual. If enough NAPL is disposed, it will exceed the amount left in near-surface soils in residual saturation and continue to migrate downward; owing to the apparently low specific gravity of the NAPLs in the likely source areas, downward migration will continue until the NAPL reaches the water table. Because of the immiscibility of the NAPL with water and the density of the NAPL mass relative to water, the NAPL will tend to float on the water table, with a minimal degree of mixing. If enough NAPL is disposed, a sizeable volume of NAPL can accumulate at the water table; after reaching the water table, subsequent migration of the NAPL in the short term can occur in three directions: 1) downgradient, following the slope of the water table; 2) vertically downward by a limited amount, whereby the NAPL displaces groundwater directly beneath it due to its accumulated weight; and 3) laterally outward in all directions from the center of the NAPL mass, based on outward-directed hydraulic forces due to the thickness of the NAPL - these are partially balanced by surface tension forces (which tend to hold the NAPL in place). Lateral migration of the NAPL by the first and third mechanisms would tend to spread it out from the specific location(s) of disposal. A possible scenario for a conceptual NAPL model in Area 7 is that sufficient lateral migration has occurred in Area 7 to create a semi-continuous zone of NAPL distribution in the area south of the basketball courts. A semi-continuous zone of light NAPL may also exist near the top of the saturated zone in Areas 4 and 11, and probably in Area 12, based on soil gas and subsurface soil data.

Two additional modes of migration can affect light NAPLs, on a generally longer time scale than the three mechanisms noted above. The first of these is due to episodic fluctuation of the water table; though most of this movement will be vertical, some horizontal migration is also probable. Evidence for such horizontal migration was found in Area 7, where the width of the NAPL zone (about 100 feet as defined by subsurface soils) is considerably greater than that of the geophysical anomalies in the same areas (about 40 feet). Provided that the liquid wastes and the metallic material were disposed in the same locations, the geophysical anomalies are a better indication of initial disposal patterns, owing to the immobility of the solid metallic material that constitutes these anomalies. Though contaminant migration appears likely, such movement has not been of a large scale since the time of contaminant disposal, as the highly contaminated zone remains centered on the geophysical anomalies; rather, the net effect of this type of migration has been a spreading out of the contaminant mass.

A second mode of NAPL contaminant movement that can occur for a period after disposal is through slow infiltration of NAPL into low-permeability units such as sandy silts and clayey silts. Once a NAPL comes in contact with low-permeability units in the unsaturated zone, resultant lateral migration may be enhanced while downward migration is hindered. The NAPL mass could become perched on low permeability zones, accumulate or pool on the surface of the strata and potentially migrate laterally depending on the orientation of the low-permeability strata and the hydraulic gradient in the aquifer. Migration through such zones will depend on the thickness, density and viscosity of the NAPL mass along with the effective pore size of the strata. If the NAPL continues downward, it can be expected to eventually reach the water table. Where low-permeability units are present at or near the water table, they can become infiltrated with NAPL, especially in areas where a large head of NAPL directly overlies these units. This process is fostered by the ability of organic solvents to drive the interlayer water out of clay minerals, chemically altering and desiccating the minerals, which in turn increases the

permeability of clay-bearing units. In addition, the extended period of time available for NAPL to infiltrate lower-permeability units favors the ultimate penetration of NAPL into such zones. Evidence for considering this conceptual model scenario exists in Area 7: the distribution of NAPL masses is controlled primarily by the depth of saturation, rather than by stratigraphy; where silty units are present at or near the water table, these units have become invaded with NAPL material. In fact, some of the highest head-space and contaminant concentrations are present in the silty units. The primary significance of this pattern is for remediation, because cleanup of a NAPL mass in a silty unit may require considerably more time than cleanup of NAPL in a sandy interval.

Future source investigations should take into account the existing information and hypotheses described above for zones of NAPL contamination in the source areas. These investigations should be conducted in a phased approach to confirm and characterize any NAPLs present above or below the water tank.

Volatilization

Because of their volatility, VOCs in contaminant source areas will tend to dissipate through time, via contaminant evaporation that transports contaminants in all directions outward from the contaminant source. Contaminant volatilization accounts for the fact that VOCs can be detected in soil gas sampling programs. This capability allows the delineation of likely contaminant source areas, as has been illustrated in Phases I and II of the RI. As it has been shown that extensive contamination exists in Area 7, the proper measure of the tendency to volatilization from these zones is vapor pressure (in assessing the tendency of contaminants to volatilize from groundwater where they are in a dissolved state, the proper measure of this tendency is the Henry's Law constant).

Contaminant volatilization in contaminant source areas proceeds most readily in permeable soils, and near the upper or lateral margins of the contamination, where soil air is present. As the component VOCs in a contaminant source area have different propensity to volatilization (measured by vapor pressure; see Table 4-10), the composition of the contaminant source will change through time; more-volatile compounds will tend to escape to the atmosphere more readily than less-volatile compounds. In source Area 7, this pattern is illustrated by the relatively large proportion of PCE present in subsurface soils throughout this area. In subsurface soils of Area 7, the ratio of PCE to TCA ranges from 0.03 to 31.2, with a median of 0.67. In soil gas samples collected at locations overlying these subsurface soils in Area 7, however, the ratio of PCE to TCA is distinctly lower, ranging from 0.01 to 2.94, with a median of 0.29. This contrast shows the greater tendency of the more-volatile TCA to escape from the subsurface toward the atmosphere; the end result is that through time, the contaminant source in Area 7 contains progressively higher proportions of less-volatile constituents such as PCE, xylene, and naphthalene.

Solubility

Although the primary groundwater contaminants of concern in the study area are not highly soluble in water, they are soluble enough to be transported for considerable distances in

groundwater at concentrations above applicable health standards such as MCLs. The solubilities of the contaminants of concern are listed in Table 4-10. VOC contaminants in contaminant source areas can dissolve in water primarily through the following processes: 1) dissolution in infiltrating precipitation that passes across residual concentrations of VOCs present in the unsaturated zone - such dissolution is relatively important, because of the high surface-to-volume ratio characteristic of residual concentrations; and 2) dissolution by groundwater in the saturated zone - as most sources in the study area contain light NAPLs compounds and the permeability of these zones to water is relatively low, most of this dissolution takes place near the margins of the areas of high contamination.

In general, compounds at similar concentrations in a contaminant source area will tend to dissolve into groundwater in proportion to their solubilities in water. For compounds present at different concentrations in a source area, the influence of solubility in contaminant transport can be observed in comparisons of contaminant ratios in the groundwater to the same ratios in the source area. For example, the ratio of 1,1-DCA to TCA in Area 7 subsurface soils is generally low; where it can be computed, it is generally 0.01 to 0.15; in groundwater downgradient from Area 7, this ratio is higher, most commonly between 0.2 and 1.5. As 1,1-DCA has a higher solubility in water than TCA (see Table 4-10), it is more effectively transferred from source subsurface soils to the groundwater. Similar patterns are present for both 1,2-DCE and 1,1-DCE compared to the lower-solubility TCA.

The opposite pattern is present for PCE. As noted in subsection 4.5, the ratio of PCE to TCA in subsurface soils in Area 7 is generally between 0.08 and 2.7; in groundwater downgradient from Area 7 this ratio is lower, being between 0.02 and 0.17. This pattern indicates that PCE is less mobile than TCA, a characteristic that has been noted at numerous groundwater contamination sites. Lower mobility for PCE than for TCA is most likely a function of lower solubility of PCE in water (see Table 4-10), and, conversely, higher degrees of sorption and retardation for PCE. Low solubility in water probably accounts for the fact that PAHs, PCBs, pesticides, and metals, though locally abundant in several source areas, are not present in groundwater at concentrations above 50 ppb. Of these compounds, only naphthalene and 2-methylnaphthalene were detected in groundwater samples, which is consistent with the fact that they are the only compounds in these groups with solubilities above 1 ppm (Montgomery and Welkom, 1990). The inverse relationship of solubility and sorption in the study area is also supported by the results of subsurface soil sampling in portions of the contaminant plume that are outside of contaminant source areas, as discussed in subsection 4.5.2.

Biodegradation

Once VOCs are disposed in subsurface soils in the likely source areas, a major process affecting their fate is biodegradation. Reductive dechlorination has been found to be a major mode of biodegradation of chlorinated ethanes and ethenes such as TCA, TCE, and PCE (e.g., Vogel et al., 1987; LeSage et al., 1990). This degradation process proceeds under anaerobic conditions, and results in the sequential loss of chlorine atoms; compounds containing one less chlorine atom are formed in each biodegradation step. The transformation of vinyl chloride to carbon dioxide is a biodegradation process, but this proceeds in an aerobic environment (Hartmans et al., 1985). Another biological transformation is from 1,1-DCE to 1,1-DCA (Baek and Jaffe, 1989), but this

TABLE 4-10
PHYSICAL AND CHEMICAL PROPERTIES OF SELECTED CHEMICALS (a)

Compound	Acronym	Molecular Weight (g/mole)	Vapor Pressure (mm Hg)	Specific Gravity (Water = 1)	Solubility (mg/l)	H (atm-m ³ /mole)	Log (Kow)
Vinyl Chloride	VC	62.5	2,530	0.91	2,700 (f)	1.2	0.6
Chloroethane	--	64.52	1,011	0.90	5,740	1.1E-02	1.43
Acetone	--	58.08	180	0.79	Miscible	3.97 x 10 ⁻⁵	- 0.24
1,1-Dichloroethene	1,1-DCE	96.94	591	1.22	2,500 (e)	2.1 x 10 ⁻²	2.13
1,1-Dichloroethane	1,1-DCA	98.96	182	1.17	5,500	4.3 x 10 ⁻³	1.79
cis-1,2-Dichloroethene	cis-1,2-DCE	96.94	(b)	1.28	3,500	(c)	1.74 (d)
trans-1,2-Dichloroethene	trans-1,2-DCE	96.94	265	1.26	6300	6.6 x 10 ⁻³	2.09
1,2-Dichloroethane	1,2-DCA	98.96	64	1.24	8,700	9.1 x 10 ⁻⁴	1.48
2-Butanone	MEK	72.11	71.2	0.80	353,000 (g)	4.66 x 10 ⁻⁵	0.26
1,1,1-Trichloroethane	TCA	133.4	96	1.34	1,175	1.8 x 10 ⁻²	2.47
Trichloroethene	TCE	131.39	58	1.47	1,000	9.9 x 10 ⁻³	2.53
Benzene	--	78.11	76	0.88	1,780	5.5 x 10 ⁻³	2.11
4-Methyl-2-Pentanone	MIBK	100.16	15	0.80	17,000	1.49 x 10 ⁻⁵	1.09
Tetrachloroethene	PCE	165.83	14	1.63	150	1.5 x 10 ⁻²	2.6
Toluene	--	92.14	22	0.87	515	6.7 x 10 ⁻³	2.65
Ethylbenzene	--	106.17	7.08	0.87	152	6.6E-03	3.13
Xylene (h)	--	106.17	8.29 (i)	0.86	152	6.3E-03	3.13
bis (2-Ethylhexyl) Phthalate	--	390.57	1 x 10 ⁻⁷	0.985	0.041	1.1 x 10 ⁻⁵	4.2

Vapor Pressure = Vapor pressure at 20 C

Density = Density of pure liquid

Solubility = Solubility in water at 20 C

H = Henry's Law Constant

Log Kow = Log (octanol-water partition coefficient)

(These values will vary to some degree
since they are derived from different studies)

(a): Values from Montgomery and Welkom (1990)

(b): Value pressure unknown; probably near 265 mm Hg

(c): H is unknown because vapor pressure is unknown;

however, using a vapor pressure of 265 mm Hg, H = 9.7 x 10⁻³

(d): Value denotes log Koc, or log (organic carbon partition coefficient)

(e): Values found in literature range from 210 to 6,400 ppm

(f): Values found in literature range from 60 to 9,150 ppm

(g): Value given at 10 C

(h): Values chosen for xylene were the median values among data from all three isomers

(i): Median value for vapor pressure at 25 C

involves no chlorine loss. In addition to these biologically-mediated transformations, several abiological transformations have been reported. These include the formation of 1,1-DCE from TCA (Vogel et al., 1987), of acetic acid from TCA (Vogel and McCarty, 1987), and of ethanol from chloroethane. Both biological and abiological transformations are summarized in Figure 4-37. This degradation scheme includes specific pathways that do not appear to be major pathways in the study area, such as the degradation of TCE to trans-1,2-DCE. In addition, the degradation of chloroethane and ethanol have not been verified, but have been suggested in the above references; these pathways are therefore shown as dashed lines.

Several of the degradation processes shown in Figure 4-37 are most likely to have occurred in the study area, particularly in certain areas. As noted above, reductive dechlorination requires an anaerobic environment to proceed. The existence of an anaerobic environment in the likely source areas is supported by the subsurface soil analytical results: in Areas 7, 11, and 12, there are high concentrations of xylene in the highly-contaminated intervals, along with other non-chlorinated aromatic (e.g., toluene) compounds. The significance of these results is that these compounds are readily degradable in an aerobic environment. Chiang et al. (1989) have noted the negative correlation of the BTX (benzene, toluene, and xylene, which are aromatics) compounds with dissolved oxygen (DO) concentration in groundwater. They concluded from studies of a sandy aquifer that BTX removal was directly related to DO concentration, with BTX being absent when DO concentrations were greater than 0.9 mg/L. Conversely, the presence of BTX compounds in the high contaminated portions of Areas 7, 11, and 12 may be interpreted to suggest that DO concentrations are low in these areas, meaning that conditions are either reducing or anaerobic. On the contrary, it is possible that aerobic conditions are present in the immediate vicinity of the highly contaminated portions of Areas 7, 11, and 12, however such a large volume of contaminant mass may have been initially present that the entire BTX components of the contaminant mass hasn't had time to degrade. Dissolved oxygen data was not collected during this study so it is not possible to determine the processes that are or have been occurring.

Contamination in Area 4 is different from that in Areas 7, 11, and 12, in that there are relatively small concentrations of the readily-degraded BTX compounds; rather, alkanes were noted at high concentrations. As the alkanes are less susceptible to degradation than the BTX compounds, the consumption of oxygen in the subsurface at Area 4 is likely to be less than in Areas 7, 11, and 12; in turn, conditions may not be anaerobic, and the reductive dechlorination type of degradation may not be as extensive in Area 4. This is consistent with what is observed in subsurface soil and groundwater samples near Area 4: the concentrations of daughter products formed through reductive dechlorination (1,2-DCE, 1,1-DCA, and 1,1-DCE) are at relatively low to undetectable levels in subsurface soils in Area 4, and in groundwater samples downgradient from Area 4 (e.g., at MW130). If the chlorinated VOC portion of the Area 4 plume begins to migrate within the aquifer in the vicinity of the Area 11 source/plume, enhanced degradation of these VOCs may occur due to the anaerobic conditions believed to exist in this area. At which point enhanced concentrations of degradational daughter products may be observed. This may be difficult to distinguish from the degradational processes which are already occurring in Area 11.

Biodegradation probably accounts for the existence of a major fraction of 1,1-DCA, 1,2-DCE, chloroethane, vinyl chloride, and some of the TCE present in groundwater and subsurface soils; all of these can form through reductive dechlorination of higher-chlorinated compounds such as PCE, which occurs in an anaerobic environment. The likelihood of an anaerobic environment in several of the likely contaminant source areas has been established above. Biodegradation is also suggested in the study area because of the correlation of certain of the daughter compounds with their likely parent compounds. Though some daughter compounds can form through degradation of different parent compounds, 1,1-DCA forms during biodegradation of TCA, while 1,2-DCE forms through the biodegradation of TCE which in turn may be formed through the biodegradation of PCE. In groundwater contaminant plumes where biodegradation appears to have occurred owing to the presence of relatively abundant daughter products, one of the following two patterns appears to hold: 1) in plumes with significant proportions of both TCE and TCA (i.e., TCE/TCA ratio greater than 0.15), the TCE biodegradation daughter product 1,2-DCE is present at concentrations greater than 1,1-DCA, a TCA daughter product - this applies to the Area 7 and Area 18 plumes, and probably the Area 16 plume; 2) in plumes with high TCA but low TCE (TCE/TCA ratio less than 0.15), 1,1-DCA is present at concentrations greater than 1,2-DCE - this applies to the Area 8 plume and the upgradient portion of the Area 9/10 plume. In other words, 1,2-DCE tends to follow its parent compound, TCE, while 1,1-DCA tends to follow its parent compound, TCA; this correlation of parent compound with daughter product supports the process of biodegradation in the contaminant plumes listed. In the other identified contaminant plumes, the concentration of daughter products is too low to discern definite patterns; in some of these cases such as Area 4, the daughter products are at low proportions because significant biodegradation does not proceed, which in turn is probably due to the fact that the requisite anaerobic environment apparently does not exist.

Biodegradation in the subsurface environment also affects the distribution of non-chlorinated compounds. In fact, all of the non-chlorinated VOCs present at elevated concentrations in source areas are readily susceptible to biodegradation in an aerobic environment. This includes the aromatic compounds xylene, toluene, ethylbenzene, and the ketones including acetone and 2-butanone. Potential degradational daughter products include phenols, catechol, cis-1,2-dihydroxy-1,2-dihydrobenzene, benzyl alcohol, benzaldehyde, benzoic acid and other carboxylic acids. These compounds were not analysed for in this study. The carboxylic acids are readily metabolized by most microorganisms. Because of the abundance of the aromatic compounds in the contaminant sources in Areas 7 and 11, combined with the relative ease with which these compounds are degraded, the aromatic compounds have a major influence on the evolution of the contaminant plumes downgradient from these areas.

In particular, the rapid degradation of aromatics in and near both the Area 7 and Area 11 sources appears to create a reducing chemical environment, which in turn fosters the biodegradation of TCA, PCE, and TCE through reductive dechlorination. Owing to the rapid degradation of the aromatic compounds in these areas, contaminant plumes for these compounds are relatively short. The pattern of rapid degradation of aromatics is facilitated by the presence of relatively permeable sandy subsurface soils and a shallow water table in Areas 7 and 11, which in turn allow relatively easy penetration of oxygen to the unsaturated zone and to shallow groundwater just below; these are the intervals that contain the elevated aromatic compounds, and oxygen is the critical component in the degradation process. Downgradient from the end of

the aromatic compound plumes, oxygen is no longer consumed by the degradation of these compounds. The abundance of free oxygen changes the chemical environment from reducing to oxidizing, which means that reductive dechlorination of the chlorinated VOCs ceases. This pattern is vividly illustrated in both the Area 7 and Area 11 plumes: downgradient from the disappearance of BTEX compounds in these plumes, no discernible changes in the proportion of parent to daughter compounds is seen; the chlorinated VOCs, resistant to biodegradation in these oxidizing conditions, migrate from these locations for long distances downgradient (the exception is vinyl chloride, which is susceptible to degradation under oxidizing conditions - it thus parallels the BTEX compounds). This pattern is also observed in the Area 4 plume where there appear to be relatively minor amounts of BTX compounds relative to alkanes. A resultant oxygen-rich environment could be presumed to be present in the vicinity of the Area 4 plume. This oxidizing environment would in turn hinder the degradation of the chlorinated VOCs such as TCE and TCA accounting for the relatively low concentrations of associated degradational daughter compounds such as DCE and DCA.

4.9.3 Groundwater Contaminant Plumes

The chlorinated organic compounds TCA, TCE, PCE, 1,1-DCA, 1,1-DCE, and 1,2-DCE all form relatively extensive groundwater contaminant plumes in the study area. The mobility of these compounds in groundwater is due to their presence in contaminant source areas at relatively high concentrations (in the ppm range), and relatively high solubilities (more than 100 ppm) in water. Based on the distribution of these compounds in the groundwater identified from the Phase I and Phase II studies, eleven distinct plumes have been defined in the study area. The Area 4, Area 7, Area 8 and Area 9/10 plumes are relatively well-defined, while others are either based on only several wells, or plume boundaries are not well known.

The Area 7 plume is the largest and best characterized contaminant plume in the study area; it appears to extend from a general area west of Alpine Road, trending west with a slight influence north to a point just beyond Eleventh Street and just south of Harrison Avenue (see Figure 4-31). This plume begins in Area 7 and gradually migrates from the shallow portion of the aquifer system to depths of about 200 feet between MW103 and MW101; the maximum depth of the plume is not known. Downgradient (west) of MW101, this plume affected residential wells across a wide area, necessitating hookups of these residences to municipal water supplies. Downgradient of MW101, the Area 7 plume probably stays at about the same elevation; as land surface elevations decline to the west of MW101, the plume probably is present at shallower depths (based on several observations and on groundwater gradients).

Both the unconsolidated and Galena-Platteville aquifers have been affected by the Area 7 plume in its upgradient portion; in downgradient portions (west of 20th Street), the Area 7 plume is primarily limited to the unconsolidated aquifer because of the gradual westward erosion of the Galena-Platteville, which discharges groundwater to the unconsolidated that replaces it laterally. The extent of penetration of the Area 7 plume into deeper units (Glenwood Formation or below) is not well known. The Glenwood likely acts as an aquitard that hydraulically separates the Galena-Platteville from the underlying St. Peter Sandstone, as illustrated by large head differences in the eastern portion of the study area, where heads in the St. Peter are drawn down from municipal pumping in the Rockford area. It should be noted that there is a potential

for downward migration through the Glenwood, as there is no such thing as a completely impermeable unit; however, the magnitude of the flow is not known. Because the top of the Glenwood represents an unconformity, all or part of this unit may not be present in northern Illinois (Willman et al., 1975). Hence, there is a potential for portions of the Area 7 contaminant plume to migrate down into the St. Peter Sandstone, a municipal water-supply aquifer, in areas of deep pumping where the Glenwood Formation is not present. In addition, measured heads in the St. Peter suggest that contamination present in this unit where the Glenwood is absent (i.e., near 11th Street) can migrate to the east toward Alpine Road. It is possible that the deep sandstone unit well UW16 (located near the corner of Harrison Avenue and Alpine Road) could affect the plume; however, the presence of the Glenwood Formation in this area and the distance of UW16 from Area 7 make this possibility unlikely.

The Area 7 plume shows coherent behavior regarding relative contaminant abundances. In general, across the plume, the ratios of the major contaminants to TCA (the most abundant contaminant) fall within a limited range. These ratios appear to reflect the composition of the Area 7 contaminant source, based on comparison of groundwater results to subsurface soil and soil gas sampling results; this is also supported by the data collected in characterizing groundwater, soils, and soil gas in other areas (Areas 4 and 11), as well as the fact that the contaminant ratios in other plumes tend to fall within different ranges (e.g., lower TCE/TCA ratios in Areas 4 and 8 plumes than in the Area 7 plume; higher TCE/TCA ratios in Area 16 plume). The Area 7 plume also behaves coherently in that contaminant concentrations decline steadily in the downgradient direction (west-northwest). Taken together, these patterns support the idea that the Area 7 plume originates from a single, large contaminant source near the east end of Balsam Lane.

The Area 8 contaminant plume has the second-highest concentrations of chlorinated VOCs in the study area. As the Galena-Platteville aquifer is present at shallow depths there, a major portion of this plume is in that unit. The Area 8 plume has its own distinctive fingerprint, with a low ratio of TCE to TCA, and relatively high proportions of 1,1-DCE compared to other plumes. These patterns have held from Phase I (when sampling in the Area 8 plume was more extensive) to Phase II, and across the entire plume, allowing discrimination of the Area 8 plume from the Area 7 plume located a short distance to the south.

The Area 9/10 contaminant plume has the third-highest concentrations of chlorinated VOCs in the study area. This plume appears to extend from an area just west of Eleventh Street on Harrison, trending southwest and extending to the Rock River, though the total length is unknown; it is probably confined to the unconsolidated aquifer. The plume also has a somewhat variable composition chemically: the upgradient portion has low ratios of TCE to TCA and high proportions of biodegradation daughter products, while two downgradient wells have high TCE/TCA ratio and/or high PCE concentration. It is not known whether these differences reflect variability within the same plume, or if two separate plumes are present; there are not enough monitoring wells in the downgradient portion to answer this question, or to define the downgradient extent of the Area 9/10 plume. It is likely, however, that this plume signals the presence of a contaminant source a short distance upgradient (probably near the southern boundary between Areas 9 and 10), based on the abundance of PCE and total chlorinated VOCs relative to wells just upgradient. The presence of a high proportion of degradation daughter

products could be accounted for by the presence of high concentrations of aromatic compounds (toluene and xylene) which may have migrated to this area from the Area 11 plume or another undefined source near Area 9/10; these compounds foster the biodegradation process, probably through the creation of an anaerobic environment in the subsurface.

The Area 4 contaminant plume is considerably smaller than those discussed above. The plume appears to be generated from an area south of Harrison Avenue, approximately 1500 feet east of Eleventh Street trending northwest to a vicinity north of Harrison Avenue and just east of Eleventh Street. This plume has a distinctive contaminant fingerprint based on the fact that TCA constitutes about 95% of total detected VOCs. The high-TCA fingerprint is replicated in both soil gas and subsurface soil samples in and adjacent to Area 4. The proportion of biodegradation daughter products is lower than in most other plumes, perhaps because of low proportions of aromatic compounds in source soils. The correspondence of sampling results from various media suggests that the Area 4 plume derives from a single source located in the upgradient portion of Area 4.

The Area 11 contaminant plume consists primarily of aromatic compounds (toluene, xylene, and ethylbenzene), though elevated concentrations (up to 2,900 ppb) of several chlorinated VOCs are also present. As defined by the presence of the aromatic compounds, the Area 11 plume is being generated from an area just east of Eleventh Street and just north of Harrison Avenue trending westward to an area midway between Kishwaukee Street just north of Harrison Avenue. The plume of chlorinated VOCs is shorter, with a leading edge existing just west of Eleventh Street; the reasons for this may be that the chlorinated VOCs have not been present in the source soils for as long, that the source volume of chlorinated VOCs was smaller, or that degradation of the chlorinated VOCs has contributed to its shorter plume length. The Area 11 plume appears to affect the relative concentrations of chlorinated VOCs that originate from other areas, owing to the presence of high concentrations of the aromatics. The degradation of the latter consumes oxygen, which creates an anaerobic environment favorable to the biodegradation of the chlorinated VOCs. This degradation occurs near the upgradient margin of the Area 9/10 plume, and results in high concentrations of daughter products 1,1-DCA and chloroethane, as well as lower concentrations of vinyl chloride.

Of the other contaminated areas at the site, the Area 15, Area 18, and Area 19 plumes contain relatively low (less than 300 ppb total VOCs) contaminant concentrations; these plumes also do not appear to be very long. The Area 16 and Area 17 plumes also contain low contaminant concentrations; however, the lateral and longitudinal extent of these plumes are not known. Higher VOC concentrations (both chlorinated and non-chlorinated) are present in the Area 13 plume; however, the extent of this plume is also unknown.

Once contaminants have reached the groundwater, a major retarding factor on their migration rate is their susceptibility to adsorption. In general, the contaminants of concern in the study area have relatively low solubilities in water (less than 1%). This hydrophobic quality means that they are susceptible to adsorption onto solid materials in the aquifers through which they migrate. The solid materials that are most effective in adsorbing organic contaminants are those with high ratios of surface area to volume, such as organic carbon and clay minerals. Though there were problems with the analytical results for total organic carbon samples, visual

observation of formation samples suggests that the organic carbon content in the unconsolidated aquifer is low in the study area. Clays are locally abundant in the unconsolidated aquifer, and probably contribute significantly to the process of sorption of contaminants.

As the susceptibility of a contaminant to sorption is generally inversely related to its solubility in water, low-solubility contaminants such as PCE, naphthalene, and PCBs should be most retarded in their migration in groundwater. As noted above, PCBs appear to be immobile and naphthalene has very limited mobility in groundwater. PCE has migrated more than these low-solubility compounds, but considerably less than more-soluble contaminants such as TCA and TCE. The PCE Area 7 groundwater plume appears to be considerably shorter than that of the other chlorinated organics.

4.9.4 Operable Unit, Phase I, and Phase II Groundwater Plumes

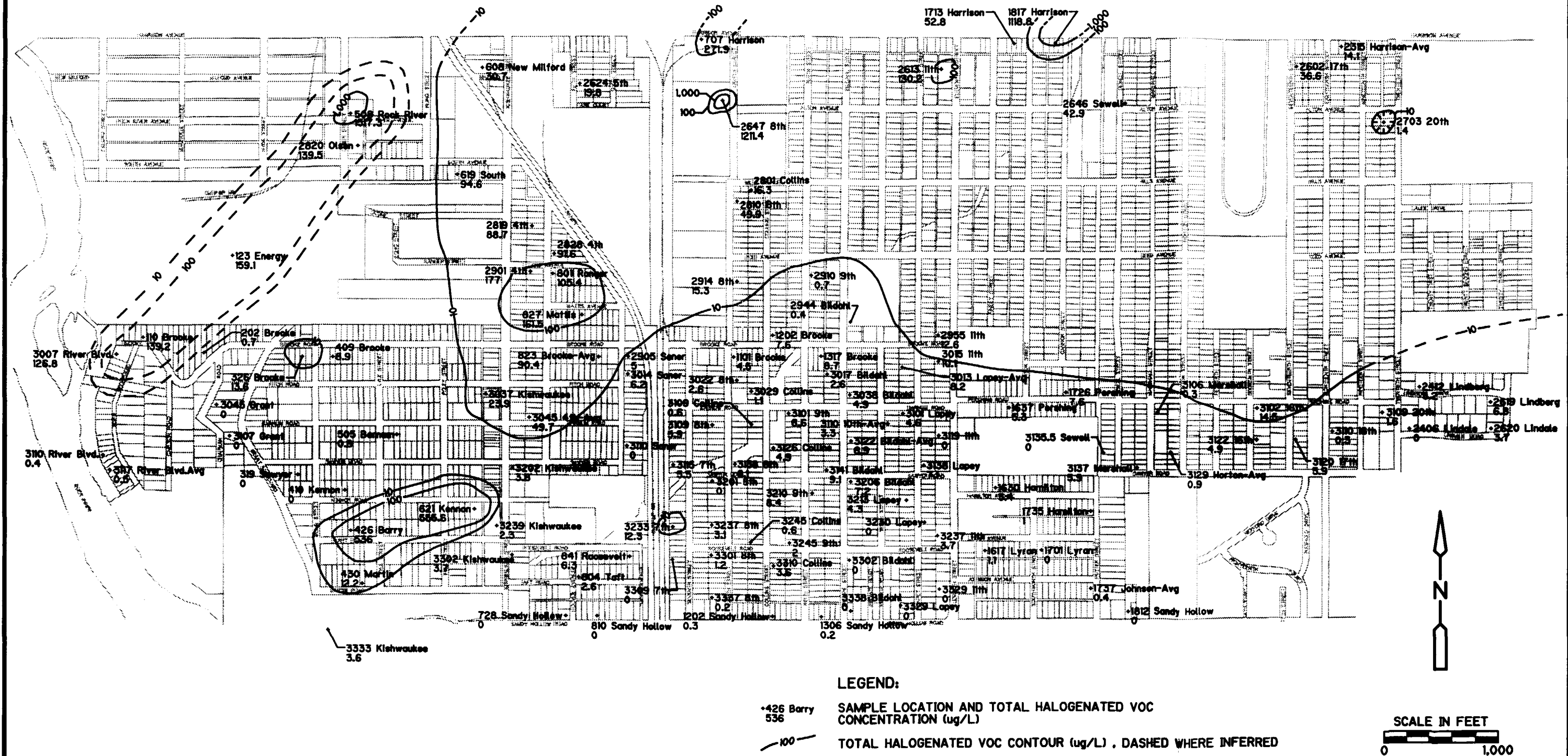
Comparison of groundwater plumes from the Operable Unit (1990), Phase I (1991), and Phase II (1993) indicates that their general shapes are similar, as shown in Figures 4-39, 4-40, and 4-41. The Operable Unit plume (Figure 4-39) extends from just east of 20th Street to near the Rock River. Concentrations shown in Figure 4-39 are generally less than 10 µg/L in the southern portion of the sampled area, with localized areas having greater than 100 µg/L. Along and near Harrison Avenue in the northern portion of the sampled area, concentrations locally exceed 1,000 µg/L. The origin of the plume located in the northwestern part of the sampled area is not known. The majority of the wells sampled during the Operable Unit were from private residences and a few were located on industrial properties.

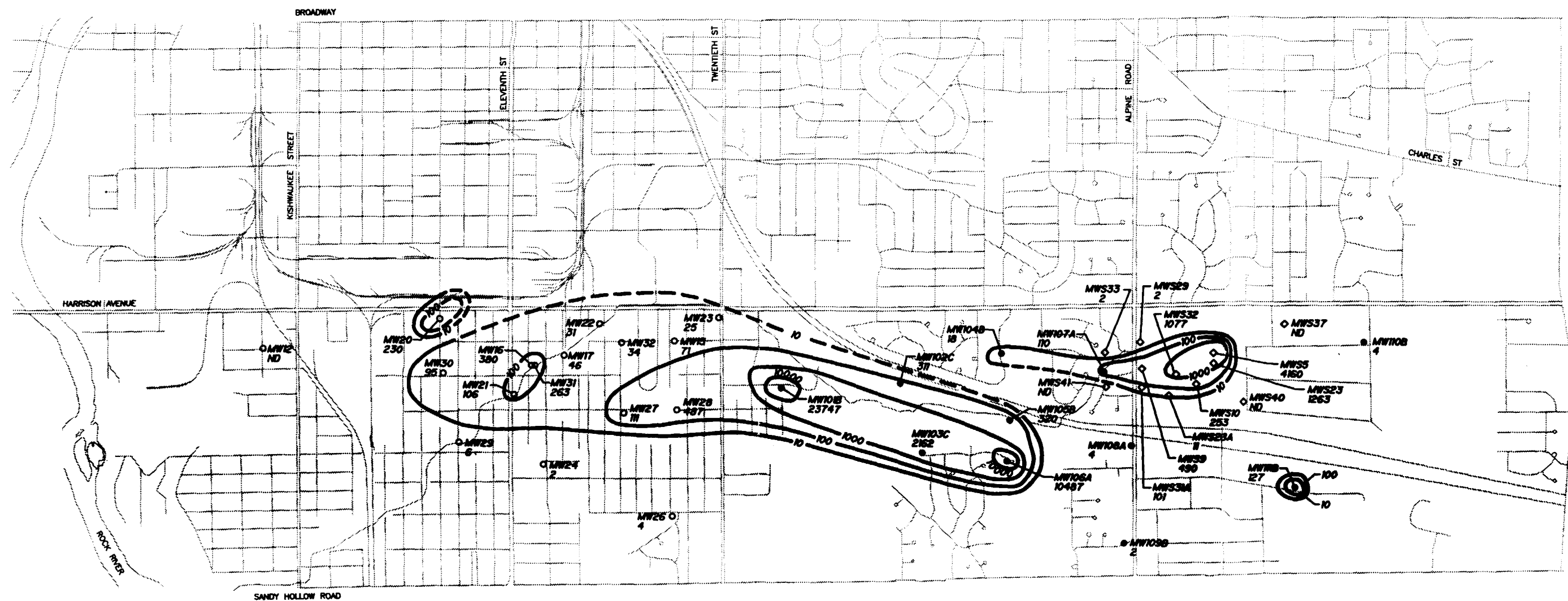
The distribution of Phase I halogenated VOCs shows one plume originating southeast of the intersection of Harrison Avenue and Alpine Road (Area 8), and a larger plume starting east of MW106 (Area 7) and extending west of 11th Street. The plume at MW111B appears to be a localized one and is not part of the other plumes. The plume at MW20 corresponds to the Area 9/10 plume identified in the Phase II investigation.

The Phase II halogenated VOC plume (Figure 4-41) is similar to but more extensive than the Phase I plume. The plumes originating in Areas 7, 8, and 9/10 are apparent in Figure 4-41. In addition, the Area 4 plume, which includes MW130, is visible along with other areas of high VOC concentration, especially in the area north of Harrison Avenue. The 10 µg/L contour line that extends from Area 7 to north of Harrison Avenue encompasses the primary area of concern. Sampling points located near the Rock River indicate that the area of concern extends to the area just east of the river. Note that some contour lines have been omitted from Figure 4-41 to reduce clutter and improve readability.

4.9.5 Contaminant Migration Rates in Groundwater

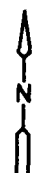
The migration rates of groundwater contaminants depend on a variety of parameters, including hydraulic conductivity, hydraulic gradient, and effective porosity; these three combine to






LEGEND:

- MW12 ISWS MONITORING WELL
- MW101 CDM/IEPA MONITORING WELL OR WELL NEST; LETTER SUFFIX INDICATES SPECIFIC WELL OF A WELL NEST
- ◇ MW59 SUNDSTRAND MONITORING WELL
- 100— TOTAL VOC CONTOUR (ug/L), DASHED WHERE INFERRED; MAXIMUM VALUE SHOWN FOR NESTED WELLS
- ND CONCENTRATION BELOW DETECTION LIMITS

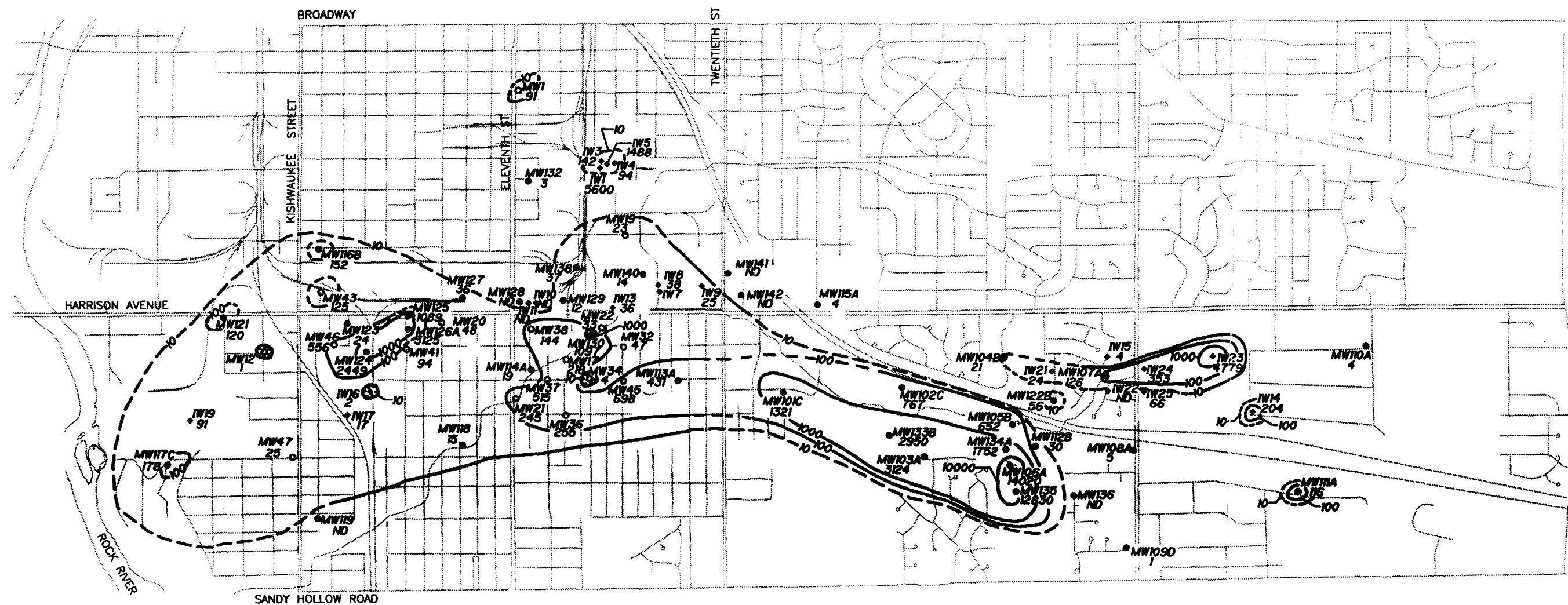


SCALE:



500 0 1000 Feet

4\CAD\168\7\R\REF\




LEGEND:

- MW12 ISWS MONITORING WELL
- MW101 CDM/EPA MONITORING WELL OR WELL NEST; LETTER SUFFIX INDICATES SPECIFIC WELL OF A WELL NEST
- ◆ IW14 INDUSTRIAL MONITORING WELL OR SUPPLY WELL
- ~100~ TOTAL HALOGENATED VOC CONTOUR (ug/L), DASHED WHERE INFERRED MAXIMUM VALUE SHOWN FOR NESTED WELLS
- ND CONCENTRATION BELOW DETECTION LIMITS



SCALE:



500 0 1000 Feet

determine groundwater velocity. The hydraulic gradients and effective porosities generally do not vary by more than an order of magnitude, hydraulic conductivity varies across several orders of magnitude throughout the study area (based on slug tests; see subsection 3.2.3).

A final parameter, the retardation factor, is specific to the contaminant in question and to the aquifer material through which migration is occurring. Retardation can be assessed by measuring the distribution coefficient between soil and water (see subsection 4.5.2). In general, less-soluble compounds such as PCE have higher distribution coefficients and thus tend to be more strongly retarded in their migration in groundwater. For a specific compound, the retardation factor appears to vary across the study area, being higher in the more silty portions of the unconsolidated aquifer east of 24th Street, and lower in the cleaner sandy parts of the unconsolidated aquifer to the west.

Due to the complex variation of these four factors in the study area, the rates of contaminant migration cannot be easily estimated across the study area. This is one reason for creating a groundwater model for the study area. Groundwater modelling can allow simulation of hydrogeologic conditions under present circumstances to create a flow model; historical information such as source loading and groundwater pumping rates can then be incorporated into the model to allow projection of contaminant migration patterns into the past and the future (the transport portion of the model). The detailed description of the groundwater model is presented in Section 5.

Another factor that affects contaminant migration rates is that of remedial activities, such as, source removal, pumping and treating of groundwater, or soil vapor extraction. Soil vapor extraction has been conducted at Suntec and source removal in the chip pit area was reported for Borg-Warner in Area 14. Groundwater pumping and treating has been employed at the Area 8 (Sundstrand) and Area 15 (Erhardt-Leimer). The overall effect of these actions is to retard the downgradient migration of the contaminant plumes, through 1) mitigation of a continuing contaminant source, 2) contaminant removal in the vicinity of the pumping wells; and 3) a reversal of hydraulic gradients in areas a short distance downgradient (i.e., downgradient under ambient conditions) of the pumping well, during the period of pumping. The extent of plume retardation in recent years is not well known, owing to a lack of detailed information about pumping rates at these locations.

A soil vapor extraction (SVE) system has been run within the past three years at the Suntec facility (Figure 4-31); this system is expected to effectively remove contaminants from near-surface soils in the area. Although this remedial action is not designed to treat the groundwater, contaminant concentrations in downgradient groundwater at locations such as MW140 are eventually expected to decline as SVE remediation progresses.

4.10 Contaminant Source Evaluation

Eight areas were identified as potential groundwater contaminant source areas in the Phase I Technical Memorandum (CDM, 1992); this identification was based on the Phase I soil gas and groundwater sampling results. After the completion of Phase I work, CDM identified six additional potential contaminant source areas through examination of IEPA and USEPA files on

industries in the study area, through site visits to portions of the study area, and by comparing the information so obtained with information previously generated in the RI. The fourteen potential contaminant source areas are shown in Figure 4-1. In Phase II, soil gas sampling was conducted in 12 of these 14 areas, and further source investigation work was conducted in eight of the areas. The results of this source investigation work are summarized in this subsection.

Area 1: Generally low concentrations of target compounds were detected in soil gas samples in Area 1 in both Phases I and II. The peak Phase I result was 4 µg/L for PCE at SG1-28, located about a half block east of Kishwaukee Street and a half block south of Kennon Road. PCE had been detected at an elevated concentration (545 ppb) in an Operable Unit residential water sample (621 Kennon Road) located about one block (roughly downgradient) to the west. Based on these results, Phase II soil gas sampling was performed using smaller intervals (about 100 feet spacing) than in Phase I, and in the area roughly upgradient from the residential well PCE hit. In Phase II, three soil gas samples had detections of PCE above 1 µg/L; the peak PCE concentration was 18 µg/L at SG1-3, located about one-half block north of the Phase I hit at SG1-28. Other significant detections of PCE were reported west of Kishwaukee Street and on either side of Kennon Road.

Phase I location SG1-28 and the three Phase II detections above 1 µg/L are all located roughly upgradient of the residential well that had the elevated PCE concentration. By comparison to other potential source areas where subsurface soil data was collected, soil gas concentrations of less than 100 µg/L was not found to be associated with subsurface source materials contaminated with the target compounds (TCA, TCE, and PCE). It is likely that the soil gas concentrations in Area 1 were not high enough to be indicative of a contaminant source nearby, and further source evaluation work, such as soil borings, was not undertaken. Nevertheless, the soil gas results from Area 1 probably have some significance, in that PCE was the compound present at elevated concentrations, in concordance with the residential well sample. The generally low and diffuse soil gas results indicate that if a contaminant source were still present, it would be dispersed and of relatively low concentration. The low soil gas concentrations may simply represent the last portions of a small contaminant source that has largely disappeared through volatilization; the absence of the more-volatile TCA and TCE is consistent with this idea. The monitoring well, MW119, located upgradient of Area 1 did not show chlorinated VOCs in the groundwater. Thus it is unlikely that the low-level soil gas is a result of volatilization from groundwater. Based on the broad occurrence (across about 300 by 300 feet) and low concentrations of PCE in Area 1 soil gas, the best explanation for the data may be that an old contaminant source has become dispersed and lost mass through contaminant volatilization.

Area 2: Similar to Area 1, soil gas results in Area 2 showed elevated concentrations of PCE but not TCA or TCE. Three Phase I soil gas samples had PCE concentrations above 1 µg/L, with a peak concentration of 120 µg/L at location SG2-9 in the west-central part of the salvage yard east of Kling Street. A residential well located about 800 feet downgradient (to the southwest, at 2820 Olsen Road) was sampled in the Operable Unit and had 127 ppb of PCE, a concentration significantly higher than nearby upgradient wells. Based on Phase I soil gas results, Phase II soil gas sampling was focused on the salvage yard east of Kling and the adjoining area just west of Kling; the sample spacing was approximately 125 feet. Phase II results showed PCE detections above 1 µg/L in the four samples nearest Kling Street, and no detections greater than 1 µg/L for

TCA or TCE. The peak PCE concentration in soil gas in Phase II was 140 µg/L at SG2-9. Combining the Phase I and Phase II hits for PCE, there is a 200 by 300-foot area adjacent to Kling Street in which all soil gas samples contained PCE at concentrations greater than 1 µg/L.

Further source evaluation was performed in Area 2, in the form of three borings drilled near the central portion of the area containing the elevated PCE soil gas hits. Consistent with the soil gas sampling results, subsurface soil samples collected from these borings displayed low, detectable concentrations of PCE at two of the three borings; concentrations were 82 ppb and 4 ppb at these locations, which were the two borings located nearest Kling Street. TCA and TCE were not detected in these samples, which is also consistent with the results of soil gas sampling. Other observations from the subsurface borings were that head-space concentrations were not detectable, and no odors or discoloration were present.

It is apparent that high concentrations of PCE are not present at the soil boring locations, which were placed in the area of peak soil gas PCE concentrations. It is possible that high PCE concentrations exist in the subsurface at other locations in Area 2. However, it is more likely that, similar to Area 1, PCE in Area 2 is present at relatively low concentrations in the subsurface throughout a fairly broad area (the area near Kling Street). This explanation appears to be consistent with the soil gas results, because of the lack of high soil gas concentrations. As noted in subsection 4.5.1, soil gas contaminant concentrations in the range of 100 µg/L were found to be inconclusive regarding whether free-product concentrations are present in the subsurface, based on comparison of soil gas to subsurface soil sampling results in Areas 2, 4, 7, and 9. Soil gas and subsurface soil results in Area 2 may instead suggest the remnants of residual concentrations, which are small-scale concentrations held in the soil by surface tension forces. Volatilization of a major portion of the original source could account for the lack of significant concentrations of TCA and TCE in soil gas samples from Area 2. In this way, Area 2 may constitute a small, old contaminant source that has lost its more-volatile components through evaporation. While a defineable contaminant source area containing free-product concentrations was not defined and may not exist in Area 2, the low to moderate concentrations of PCE in subsurface soils and soil gas may signify that Area 2 is a minor current source of contamination to groundwater; prior effects may have been larger.

Area 3: Soil gas sampling was initiated in Area 3 in order to evaluate the source of PCE and other contaminants in wells located roughly downgradient (MW46 and a Rockford Products facility well, each located about 1,200 feet west-southwest of Area 3). In Phase I, one location had soil gas sampling results exceeding 1 µg/L (PCE, TCA, and TCE were detected at 5, 4, and 3 µg/L, respectively, at SG3-1). As this location was at the northwestern corner of the Phase I Area 3 soil gas survey, additional locations west of Phase I location SG3-1 were sampled for soil gas in Phase II. At the Phase II locations, TCA was detected at 2 and 1 µg/L, while TCE and PCE were detected at 0.2 to 0.5 µg/L.

The low concentrations detected in Phase I and Phase II soil gas samples in Area 3 are most likely accounted for by volatilization of the target compounds from the contaminant plume, rather than volatilization from a source within Area 3 in the unsaturated zone. The two wells immediately upgradient (MW125 and MW126A) have TCA at 120 ppb and 610 ppb, respectively. Depth to groundwater is about 30 feet and the shallow geology is predominantly sand and

gravel. It is possible that soil gas is volatilizing off the shallow groundwater contaminant plume. This type of contaminant behavior was observed in Area 4, 12, and 14, where subsurface soil samples and groundwater samples were collected and correlated with the soil gas data.

Two other pieces of evidence suggest that Area 3 does not constitute a significant contaminant source for groundwater. First, Phase II monitoring wells MW125, MW126A and MW126B, located about 100 to 400 feet east (upgradient) of the three Area 3 soil gas hits, showed elevated concentrations (relative to wells farther upgradient) of target compounds PCE, TCA, and TCE. This observation suggests that the contaminant source affecting wells downgradient from Area 3 is actually located upgradient from Area 3. Secondly, soil gas detections in the adjacent Area 9 (located north of Area 3) were significantly higher than in Area 3. These detections, up to 331 µg/L for PCE, TCA, and TCE combined, indicate that any contaminant source in this area is probably located north of Area 3.

Area 4: Area 4 was considered a potential source area before Phase I, as a result of elevated TCA concentrations (991 ppb) in a private well at 1817 Harrison Avenue. The Phase I soil gas data showed a high concentration of TCA (3,400 µg/L at SG4-10) at a location 1,000 feet upgradient from this well. Soil gas work in Phase II comprised a tighter grid (50 to 100 feet) across the area surrounding Phase I point SG4-10. Five Phase II locations had high TCA concentrations in soil gas, ranging from 1,500 to 4,300 µg/L; these high detections were centered on the northern portion of the parking lot of the Swebco Manufacturing facility. Further source screening work was performed in Phase II, and consisted of six soil borings drilled and sampled across this parking lot. These borings showed the existence of an oily product with high concentrations of TCA (up to 360 ppm) at the top of the saturated zone. Based on its occurrence at borings SB4-1 and SB4-5 and on TCA concentrations in soil gas and in groundwater downgradient from the parking lot, the volume of TCA-contaminated soil (potential residual NAPL) in Area 4 is approximately 50 feet by 75 feet, with a thickness of eight feet. The groundwater sample from Phase II well MW130 further supports the connection of Area 4 to groundwater contamination, as TCA and TCE were detected there at a concentration of 1,000 ppb and 28 ppb, respectively, while PCE was not detected. Based on the correspondence of the soil gas, subsurface soil, and groundwater at and downgradient from Area 4 (i.e., high TCA and low to undetected TCE and PCE), the oily product observed in soil borings SB4-1 and SB4-5 appears to be part of a TCA contaminant source that affects downgradient groundwater.

Area 5: Soil gas sampling was conducted in Area 5 in order to assess the existence of a contaminant source located a short distance (500 to 2,000 feet) upgradient (east) of elevated detections of TCA, TCE, PCE, and other contaminants in numerous residential wells located near Twenty-third Street and Reed Avenue. The portion of Area 5 that was accessible for soil gas work in Phase I (Area 5a) was located east-northeast of the residential wells, on the UC Industries property. Only two Phase I samples had detections at or above 1 µg/L, with TCA detected at 2 and 1 µg/L. Owing to the low magnitude of target compound concentrations in Area 5a, further source screening was not performed there.

After Phase I groundwater sampling results were available, it was apparent that a major portion of the source of contamination noted in the residential wells was probably located upgradient from Area 5. However, Area 5b (located south of Area 5a, and about 500 feet east of the

residential wells) was still suspect for two reasons: 1) elevated contaminant concentrations in the Phase I groundwater sample from MW101B (12,000 ppb of TCA), which was considerably higher than samples collected from wells upgradient or downgradient; and 2) aerial photo evidence that shows tracks and areas of possible trenching adjacent to the Northern Illinois Gas above-ground tank facility. Of the seven locations sampled for soil gas in Phase II, only SG5-4 had contaminant concentrations greater than 1 µg/L (with 6 µg/L of TCA). A concentration of this magnitude could result from volatilization of TCA off groundwater contaminated at shallow depths, (depth to groundwater is about 20 feet) or, alternatively, could be from volatilization from a source in Area 5b. Though an Area 5b contaminant source is possible, such a source would not be large or of high concentration, because no nearby locations had elevated contaminant concentrations in soil gas.

An additional line of evidence against an Area 5b contaminant source is based on Phase II groundwater sampling results. The Phase II groundwater sample at MW101B contained contaminant concentrations considerably lower than that reported from the Phase I sample, with TCA present at 650 ppb (compared to 12,000 ppb in Phase I); this concentration is also lower than that determined for many upgradient wells in Phase II, including those at well nests MW103, 106, 133, 134, and 135. Contaminant ratios at MW101B are also similar to those found in Phase II samples upgradient from MW101. Taken together, this information suggests that the contaminants present in groundwater at the MW101 location are part of the same Area 7 contaminant plume that affects the upgradient wells. As a result, there is no Phase II information that is consistent with the existence of a contaminant source a short distance upgradient from MW101, and no evidence for a source in the subsurface at Area 5b.

Area 6: There are two different areas that have been referred to as Area 6 in various RI work: soil gas survey Area 6 and potential source Area 6. Soil gas survey Area 6 was tested during Phase I, and was located northeast of the intersection of Alpine and Sandy Hollow Roads, comprising a large industrial park about one-half mile square. Ninety-four locations were sampled for soil gas in this area, but none displayed contaminant concentrations above 1 µg/L. Consequently, Phase I soil gas survey Area 6 was eliminated from consideration as a potential contaminant source area.

The Phase I RI yielded information suggesting that a contaminant source area may exist east of potential source Area 5, and west of well nest MW103. This area was termed potential source Area 6 in the Phase I Technical Memorandum (CDM, 1992). This area was suspected as a contaminant source area for similar reasons as Area 5, based on the following: 1) elevated contaminant concentrations in the Phase I groundwater sample from MW101B (TCA at 12,000 ppb), which were considerably higher than concentrations in upgradient wells; and 2) presence of surficial disturbance, in this case in the form of a gravel pit that existed at least in the mid- and late-1980s. After completion of the Phase I Technical Memorandum, additional aerial photographs covering this area became available. These photos show that the gravel pit did not exist before the mid-1980s, and that regular agricultural planting was practiced before that time; if any contaminant disposal occurred after the pit came into existence, contaminants originating from that area likely would not have had time to migrate to the residential wells, which are located between 2,000 and 8,000 feet to the west.

Further evidence regarding potential source Area 6 was obtained in Phase II: the Phase II groundwater sample from MW101B had much lower contaminant concentrations than in Phase I. These concentrations and their ratios were consistent with those established in the wells upgradient from MW101B, suggesting that no contaminant sources (such as Area 6) affect the groundwater in an observable way in the area between MW103 and MW101B.

Area 7: Area 7 was considered a potential source area after Phase I groundwater sampling data became available. The Phase I groundwater sample from well MW106A contained 10,487 ppb total chlorinated VOCs, while wells located some 2,000 feet upgradient (MW108 and MW109) contained less than 5 ppb of total chlorinated VOCs. Geophysical work conducted in March and May 1992 showed anomalies that suggested the presence of buried metal in the subsurface soils east of MW106. Soil gas sampling conducted in Area 7 in May 1992 and February 1993 showed the presence of high soil gas readings across extensive areas east of MW106. Subsurface soil sampling in Phase II showed that high contaminant concentrations exist in the subsurface; the elevated subsurface soil concentrations corresponded quite well to the suspect area based on the soil gas results. The borings showed the existence of an oily product near the top of the saturated zone (suspected residual NAPL) and extending some distance downward (commonly 15 feet or more), with TCA, PCE, TCE, and xylene present in soil at concentrations up to 380, 260, 130, and 210 ppm, respectively. The area underlain by elevated contaminant concentrations in subsurface soils in Area 7 is approximately 300 by 1,200 feet.

Groundwater samples downgradient from Area 7 show that TCA, PCE, TCE, and other chlorinated VOCs are present in groundwater for a significant distance downgradient from Area 7, as a distinctive contaminant plume referred to as the Area 7 contaminant plume. The orientation of this contaminant plume is consistent with groundwater flow directions between Area 7 and the downgradient extent of the Area 7 plume; this consistency establishes a physical connection between the Area 7 source area and the contaminant plume. As discussed in subsection 4.8, contaminant ratios throughout the Area 7 groundwater contaminant plume are consistent within limited ranges, are concordant with those in the Area 7 subsurface soils and soil gas, and are distinct from those in most other identified contaminant plumes in the study area. These patterns establish a chemical or contaminant connection between the Area 7 subsurface soils and the Area 7 contaminant plume. Overall, the evidence gathered in the RI from sampling of soil gas, subsurface soils, and groundwater from and near Area 7 shows that the contaminated subsurface soils in Area 7 have a hydrologic and chemical connection with the Area 7 plume, and have a significant negative impact on downgradient groundwater quality.

Area 8: Area 8 was named as a potential source area in the Phase I Technical Memorandum (CDM, 1992), based on groundwater sampling only. These samples showed elevated concentrations of TCA, with significantly lower concentrations of TCE, PCE, and other chlorinated VOCs in wells downgradient from the Sundstrand Plant 6 facility on the southeast corner of Harrison Avenue and Alpine Road, while upgradient samples showed very low contaminant concentrations. Though analytical data for subsurface soils or soil gas were not collected in the RI, the groundwater data from Phases I and II clearly show a chlorinated VOC contaminant plume originating from the Plant 6 facility and extending downgradient (west).

Area 9: Area 9 was considered as a potential source area based on the same evidence as the adjacent Area 3. In both cases soil gas sampling was initiated in order to evaluate the source of PCE and other contaminants in wells located roughly downgradient (MW46 and a Rockford Products facility well, each located about 1,200 feet west-southwest of Area 3). However, Area 9 was located outside the Phase I study area; it was considered a potential source before commencement of Phase II work, when the study area was expanded. Soil gas work in Area 9 in Phase II shows the existence of moderate concentrations of TCA, PCE, and TCE (91 to 120 µg/L) at the easternmost location sampled. Locations farther to the east were not accessible. One subsurface boring was drilled and sampled at the soil gas sample location noted above, but very low contaminant concentrations (5 ppb of PCE) were detected. This one data point is not sufficient to evaluate any contributions to groundwater contamination from potential sources within the area.

Groundwater samples from wells roughly downgradient from Area 9 (MW123, MW124, MW125, and MW126A and B) show concentrations of TCA, TCE, PCE, and other compounds at levels significantly higher than in wells just upgradient (MW20 and MW127). This evidence also supports the idea of a contaminant source area in Area 9. However, the lack of access and the presence of structures (a factory and several railroad tracks) in the eastern portion of Area 9 precluded additional soil gas work or subsurface soil sampling in that suspect portion of Area 9. As a result, there is only circumstantial evidence from soil gas and groundwater sampling that suggests a contaminant source may exist in Area 9.

Area 10: Area 10 was considered a potential source area because of elevated contaminant concentrations that have appeared in past groundwater samples (prior to Phase II) of downgradient well MW20; however, the Phase II sample from MW20 showed considerably lower concentrations of chlorinated VOCs than in previous samples. Nevertheless, other wells located roughly downgradient (MW124, MW125, MW126A and B) from Area 10 showed elevated contaminant concentrations in Phase II samples, as noted in the discussion under Area 9. Soil gas samples in Area 10 showed only two samples with a target compound detected at greater than 1 µg/L (TCA at 3 and 2 µg/L, respectively). Based on these low detected concentrations and on the fact that the two samples are not adjacent to each other, it appears that the surveyed portions of Area 10 do not constitute contaminant sources to groundwater.

However, not all portions of Area 10 were accessible for soil gas sampling in Phase II. One portion of Area 10 that remains a potential source area is the southwestern corner of Area 10, located adjacent to the eastern portion of Area 9. This portion of Area 10 is still suspect because it is located upgradient of contaminated wells MW124, MW125, and MW126A and B, while also being located side-gradient of the relatively uncontaminated well MW20. The adjacent eastern portion of Area 9 is somewhat more likely as a potential source area than Area 10, owing to the detections of moderate concentrations of target compounds (91 to 120 µg/L) in one Area 9 soil gas sample. As no comparable soil gas concentrations were reported from Area 10, this area is suspect simply because of its location.

Area 11: Similar to Area 10, this area was considered a potential source area based on the presence of elevated contaminant concentrations in groundwater samples prior to 1993 from well MW20 locally approximately downgradient, and in Phase II samples from wells MW124,

MW125, and MW126A and B, located farther downgradient. In addition, oils and chlorinated organic compounds have been reported to be present in subsurface soils from an industrial site. An on-site monitoring well (MW2 on the railroad right-of-way) had 1,150 ppb TCA and 302 ppb TCE in a sample collected in November 1991; the TCE concentration is considerably higher than what is currently observed in upgradient wells. Soil gas work was performed only on the southwestern portion of Area 11; no evidence of PCE, TCE or TCA was noted from this effort. Subsurface borings across the remainder of Area 11 showed the presence of an extensive area of contaminated soils containing high concentrations of xylene, toluene, and ethylbenzene (ETX compounds) while moderate concentrations of certain chlorinated VOCs (up to 2,900 ppb of methylene chloride and 410 ppb of TCE) were reported from one or two samples. It is possible that chlorinated VOCs are present up to 20,000 ppb but were not detected due to sample dilution.

Area 11 has been shown to be a contaminant source for ETX compounds. These compounds appear to have a stimulating effect on the degradation of the chlorinated VOCs. The result is that in downgradient wells such as MW20, MW124, MW125, MW126A and B, the proportion of daughter compounds to parent compounds is significantly higher than in wells upgradient. This enhanced degradation rate is of concern because of the production of more-toxic compounds such as vinyl chloride and 1,1-DCE.

While Area 11 appears to affect the proportion of chlorinated VOCs in downgradient wells, the question of Area 11 being a source area for chlorinated VOCs can not be answered, based on the available data. The presence of TCE in a monitoring well at concentrations much higher than in wells a short distance upgradient, suggests that Area 11 is indeed a contaminant source for this contaminant. Due to the problem of the sample dilution for both soil and groundwater, it is not possible to determine chlorinated VOC concentrations in the highly contaminated area. However, it does not appear that a chlorinated VOC plume originating from Area 11 extends very far downgradient. This is based on the lack of elevated detections of these compounds in groundwater in Phase II samples from downgradient wells MW20 and MW127.

Area 12: Area 12 was investigated in order to evaluate the Viking Chemical Corporation facility that contains large solvent tanks; the area is also suspect because wells roughly downgradient (Unit Well 7, ISWS wells MW1, 2, and 5) have shown high contaminant concentrations in groundwater (generally 50 to 500 ppb of TCE in 1988). Phase II soil gas samples showed very high contaminant concentrations of TCA, TCE, and PCE (up to 22,000, 11,000, and 3,500 µg/L, respectively). Subsurface soil sampling yielded high concentrations of these compounds near the southwestern corner of the tank farm, the same area that the high soil gas samples originated from. Subsurface soil contamination may exist in the form of residual NAPL containing chlorinated VOCs and other VOCs, within the highly contaminated zone which is about 15 feet thick and extends across an area no larger than 140 feet square.

The downgradient effects of this contamination are not well-known, however, as few groundwater samples were collected downgradient. It is possible that the TCE noted in the above-mentioned wells came from the highly contaminated zone in Area 12. However, as these wells are located some 1,200 feet downgradient from Area 12 and no wells are located in the intervening area, a definite connection cannot be made between Area 12 soil contamination and

the wells located downgradient. Any potential connections with residential wells located south of Harrison Avenue would be in the downgradient (western) portion of the study area, at the Area 16 plume.

Area 13: Area 13 was considered a potential source area based on its history as an inactive solvent recovery facility (Acme Solvents Inc.). The facility was operational for 31 years, from 1955 to 1986. Activities that occurred at the facility included distilling various mixtures of organic solvents to remove contaminants. The solvents were transported to the facility's holding tanks via tankers and drums. Disposal practices at the facility are undocumented from 1955 to 1960. From 1960 to 1972, it was reported that distillates were generally returned to the company of origin and still bottoms were stored in several 2,000-gallon holding tanks and were either sold, incinerated or disposed of at the Morristown Landfill. On-site groundwater samples collected in 1988 contained up to 910 ppb TCA, 620 ppb TCE, and 230 ppb PCE. Phase II soil gas samples contained moderate concentrations of the target compounds, with levels reaching 810 ppb of TCA, 130 ppb of PCE, and 95 ppb of TCE. Groundwater samples contained up to 2,700 ppb of methylene chloride, 1,500 ppb of TCE, 1,400 ppb of 1,2-DCE (total), 1,000 ppb of benzene, 92,000 ppb of toluene, and other VOCs. Similar to Area 12, however, the downgradient extent of groundwater contamination emanating from Area 13 is not known, owing to the lack of adequate monitoring points. Low concentrations of similar contaminants are present at MW132, located about 1,400 feet to the west-southwest; however, this well is not directly downgradient from Area 13. Contaminants from Area 13 would more likely pass north of MW132, based on groundwater gradients and trend west southwest possibly crossing Harrison Avenue somewhere west of Kishwaukee Street.

Area 14: This area is located near the northern margin of the plume, on and adjacent to the former Borg Warner facility. At rear of the facility is a chip pit, which was apparently unlined for a period of its existence (before 1980). A soil sample collected from beneath the southern end of the chip pit contained 1,988 ppm of total chlorinated VOCs, including 1,020 ppm of cis-1,2-DCE, 627 ppm of 1,1-DCA, 150 ppm of TCA, 111 ppm of PCE, and 63 ppm of TCE. This sample was one of three collected in conjunction with the removal of the chip pit and the contaminated soils in late 1987 and early 1988. Phase II soil gas sampling across the area of the chip pit showed relatively low contaminant concentrations of the target compounds (up to 16 ppb of TCA). Four subsurface soil borings were drilled and sampled in Area 14 in Phase II. These borings showed low to undetectable concentrations of chlorinated VOCs, with the highest concentration being 48 ppb of 1,2-DCE (total); head-space VOC screening showed that very low VOC concentrations extend throughout the unsaturated zone. Additional source screening activity in Phase II included the installation of one monitoring well (MW138) located approximately 300 feet downgradient (west) from the chip pit; this well showed relatively low contaminant concentrations, with 13 ppb of 1,1-DCA, 9 ppb of cis-1,2-DCE, and 8 ppb of TCA. The presence of similar contaminants in RI samples of soil gas, subsurface soils, and groundwater (particularly cis-1,2-DCE, 1,1-DCA, and TCA) as what were the most abundant contaminants in the chip pit soils (sampled in 1987 or 1988, before removal) suggests that the chip pit area may have a minor ongoing impact on groundwater and soils. It is possible, however, that the groundwater flow path from Area 14 passes slightly to the north of MW138, and that impacts of Area 14 soils could be greater elsewhere.

Two other suspect areas in Area 14, located north and east of the chip pit, showed no Phase II soil gas samples with target concentrations above 1 µg/L. As a result, no additional source screening work was conducted in these portions of Area 14.

Though there is limited evidence of an ongoing current impact on groundwater by contaminated soils in the chip pit, it must be noted that past effects of these soils in Area 14 may have been much more significant. Peak concentrations of several chlorinated VOCs (cis-1,2-DCE, 1,1-DCA, and total chlorinated VOCs) from the chip pit soils in Area 14 were the highest concentrations from available data, including data reported to the USEPA in 104E forms, as well as Phase II subsurface soil sampling in various potential source areas. These peak concentrations came from the southernmost of the three samples collected from beneath the chip pit; the central sample also contained relatively high contaminant concentrations, with 579 ppm of total chlorinated VOCs; the northern sample contained 35.1 ppm of total chlorinated VOCs. These three samples were collected from borings drilled along the long axis of the center of the pit, across a distance of 70 feet. Though variable, the results contain high concentrations of contaminants of concern; the concentrations combined with their apparent extent suggest that effects on downgradient groundwater may be (have been) significant. The extent of elevated soil concentrations away from the chip pit borings appears to be small, based on the results of subsurface borings drilled and sampled in Phase II.

While current effects of the Area 14 contaminated chip pit soils are not large, the previous effects of these soils on groundwater are less well known. As the contaminated chip pit soils were apparently removed in 1987 or 1988, groundwater contaminants originating from those soils are expected to still be present downgradient. Based on a mean groundwater velocity for the western portion of the study area of 0.1 feet/day (estimated by using the hydraulic conductivities listed in Section 3), groundwater is expected to migrate approximately 220 feet in the six-year interval since the removal of the chip pit soils (contaminants would move slightly slower due to retardation effects).

However, it appears that the Area 14 chip pit soils were not a major source for groundwater contamination in the Areas 11 and 9/10 plumes; these plumes are candidates to show contamination effects from the formerly-existing chip pit soils, because they are located more than 200 feet roughly downgradient from Area 14. For both Areas 11 and 9/10 plumes, there are relatively clean monitoring wells located roughly between Area 14 and these areas (MW129 and MW138, and MW127, respectively). In addition, the contaminant ratios differ between Area 14 and the other areas, even after taking contaminant degradation into effect. As discussed in subsection 4.8, biodegradation of PCE yields TCE, which can further degrade to 1,2-DCE; a separate degradation chain characterizes TCA, which degrades to 1,1-DCA and 1,1-DCE. As these well-established degradation chains produce a mutually exclusive set of compounds, a sum of the compounds in each chain can be useful in distinguishing source inputs to groundwater; summing the compounds can also eliminate the effects of changes in the rates of degradation through time. In the chip pit soils of Area 14, the PCE-TCE-(1,2-DCE) chain accounts for about 65 to 70% of total chlorinated VOCs (and 100% in the low-contamination northern sample), with the TCA chain comprising less than 35%. However, the Area 11 plume contains less than 20% of the PCE-TCE-(1,2-DCE) chain as a proportion of total chlorinated VOCs. In the Area 9/10 plume, the PCE-TCE-(1,2-DCE) degradation chain again constitutes less than 20% of total

chlorinated VOCs. The low proportion of this chain of compounds in Areas 11 and 9/10 suggests that the formerly-contaminated chip pit soils have not greatly affected either plume.

The Area 16 plume is another candidate plume that may have had a contribution from the formerly contaminated chip pit soils from Area 14. In the Area 16 plume, the PCE-TCE-(1,2-DCE) chain constitutes between 38 and 94% of total chlorinated VOCs. This proportion is more in line with the proportion observed in the contaminated chip pit soils; though a connection cannot be made owing to the lack of adequate monitoring points, it is possible that contaminants in the Area 16 plume are derived from the contaminated chip pit soils. As noted above, the Areas 12 and 13 plumes could extend to the Area 16 plume; it cannot be stated which of these plumes (Area 12, 13, or 14), if any, is connected to the Area 16 plume, due to uncertainty in groundwater flow directions, uncertainty in the continuity of contamination in the subsurface, and the possibility of other sources upgradient of the Area 16 plume.

Section Five

Section 5

Groundwater Modeling

This section of the report discusses groundwater and contaminant transport modeling using numerical models developed by Camp Dresser & McKee Inc. The numerical models use 3-dimensional computer simulation codes to represent groundwater flow (DYNFLOW) and transport (DYNTRACK) of dissolved organic compounds at the Southeast Rockford site and the surrounding area.

5.1 Introduction

5.1.1 Purpose and Scope of the Model

- Test hypotheses Regarding Location and Timing of Contaminant Releases

Complex three-dimensional aquifer systems such as the one at Southeast Rockford do not permit simple analytical representation of the direction and rate of movement of spatially distributed contaminant releases. Uneven gradients, complex capture zones, and inhomogeneity in the vertical and horizontal directions make such a simple evaluation unreliable. Contaminant transport simulations allow hypotheses related to the location and timing of contaminant releases to be tested for their ability to reasonably reproduce the observed spatial and temporal distribution of groundwater contamination.

- Project Future Contaminant Concentrations to Support Risk Assessment

Models are a good means of estimating future contaminant concentrations in complex aquifer systems. Contaminant transport simulation can provide concentration estimates at any point in the system for use in estimates of risk to various users. Solute-transport modeling provides an indication of contaminant movement; however, additional data and analysis may be needed for a more complete description of contaminant movement. Results of the transport simulation are used to provide qualitative estimates of risk to users addressed in this report.

- Improve Remediation Design by Enabling Testing of Alternative Designs

Models are able to simulate the hydraulic and contaminant transport effects of plume containment, extraction/injection, and source elimination programs. Various remedial techniques can thereby be assessed and refined at a relatively low cost.

- Provide Effective Communication Tools

Models help interested parties to visualize system behavior. Graphic images showing water table elevation, mass transport simulation results, and site stratigraphy, for example, can convey to the public basic concepts related to groundwater flow and complex spatial relationships related to the study area.

5.2 Groundwater Hydrology

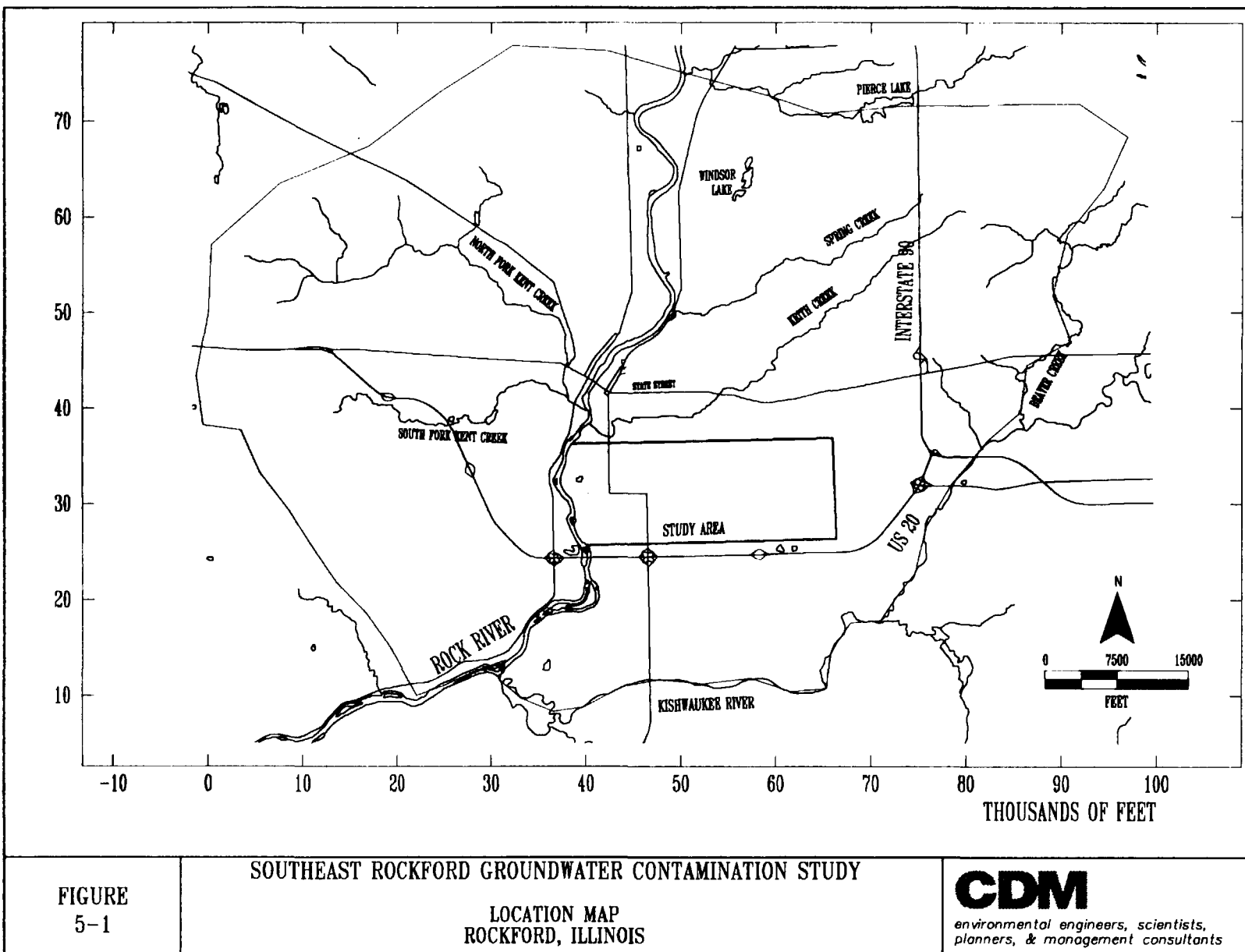
5.2.1 Groundwater Flow Patterns

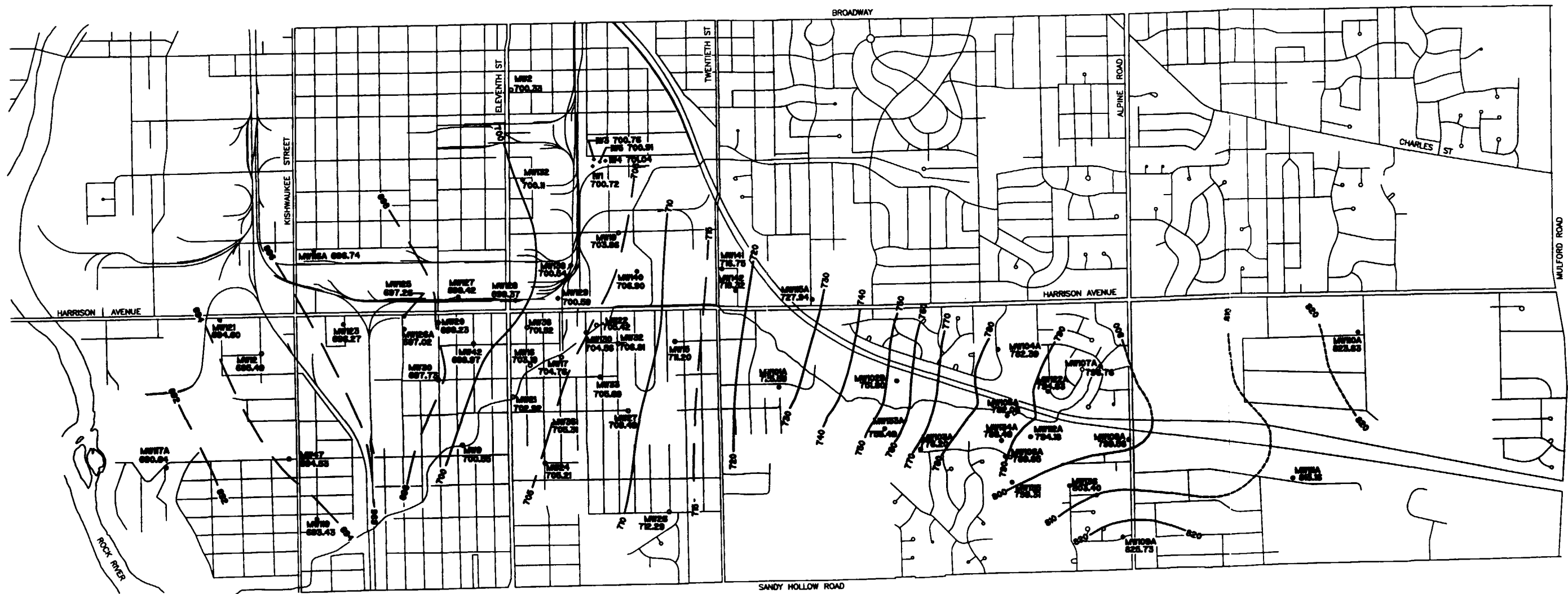
Groundwater flow patterns in the unconsolidated and shallow dolomite aquifers in the Rockford area are strongly influenced by the ground surface topography. The water table generally follows the surface topography, being higher under upland areas and intersecting the ground surface in lowland areas along rivers, lakes, and other surface water bodies. Recharge to the water table aquifer typically occurs in the upland areas and discharge occurs in the intervening lowland areas (Berg et al., 1984). Within the modeled area (Figure 5-1), the Kishwaukee and Rock Rivers are major discharge areas for the unconsolidated and shallow dolomite aquifers. Within the study area shown in Figure 5-1, the general direction of groundwater flow in these aquifers is to the west. Locally groundwater also discharges to creeks, streams, and other surface water bodies. Figure 5-2 shows the general distribution of groundwater elevations for the unconsolidated aquifer measured in monitoring wells located within the study area.

The general pattern of groundwater flow in the deep bedrock aquifers is primarily from a regional groundwater divide in north-central Illinois toward the Rock River. The regional groundwater divide is located approximately 12 miles east of the modeled area (Visocky, 1993). Recharge to these aquifers is primarily from precipitation percolating through overlying units in areas where a regional confining unit, the Maquoketa Shale Group, is not present. The Maquoketa is not present within the modeled area and its western limit roughly corresponds to the regional groundwater divide described above. Within the model boundaries, the regional flow pattern in the deep bedrock aquifers in the Rockford area is altered by local cones of depression caused by pumping wells that are part of the city's municipal drinking water supply.

Figure 5-3 shows a cross-sectional view of observed heads across the study area, from a local groundwater divide in the east to the Rock River in the west. This groundwater divide is due to an upland area between the Kishwaukee and Rock Rivers and affects the unconsolidated and dolomite aquifers. Figure 5-3 shows that there are significant vertical hydraulic gradients present within the study area. For example, at MW101 and MW103, there are relatively strong vertically downward gradients between the unconsolidated and dolomite aquifers. At location MW112 there is a large head difference of 104 feet between the two shallow wells and the deep well in the St. Peter Sandstone, indicating strong downward gradients. This head difference is largely due to the Glenwood Formation, which is a confining layer within the study area. Also of note in Figure 5-3 is the upward hydraulic gradient near the Rock River (MW117), indicating that the unconsolidated aquifer is discharging to the river in that area. Details of observed groundwater flow directions can be found in Section 3.0 of this report.

Recharge values for the groundwater model were based on precipitation data for Rockford provided by the Illinois State Water Survey. Data for the period 1955 to 1993 indicate that the mean precipitation value for Rockford was approximately 37 inches per year. Uniform recharge to groundwater of 15 in/yr for Valley Deposits and 10 in/yr for all other surficial formations were assumed based on this precipitation rate.



**LEGEND:**

- MW12 ISWS MONITORING WELL
- MW101A CDM/IEPA MONITORING WELL
- IW14 INDUSTRIAL SUPPLY WELL OR MONITORING WELL
- 100 — GROUNDWATER ELEVATION CONTOUR
- 200 — INFERRED GROUNDWATER ELEVATION CONTOUR
- — CONTOUR AT INTERVAL OF 10 FEET

NOTE:

MAP INCLUDES WELLS IN SHALLOW PORTION OF UNCONSOLIDATED AQUIFER, GENERALLY WITHIN 25 FEET OF WATER TABLE.

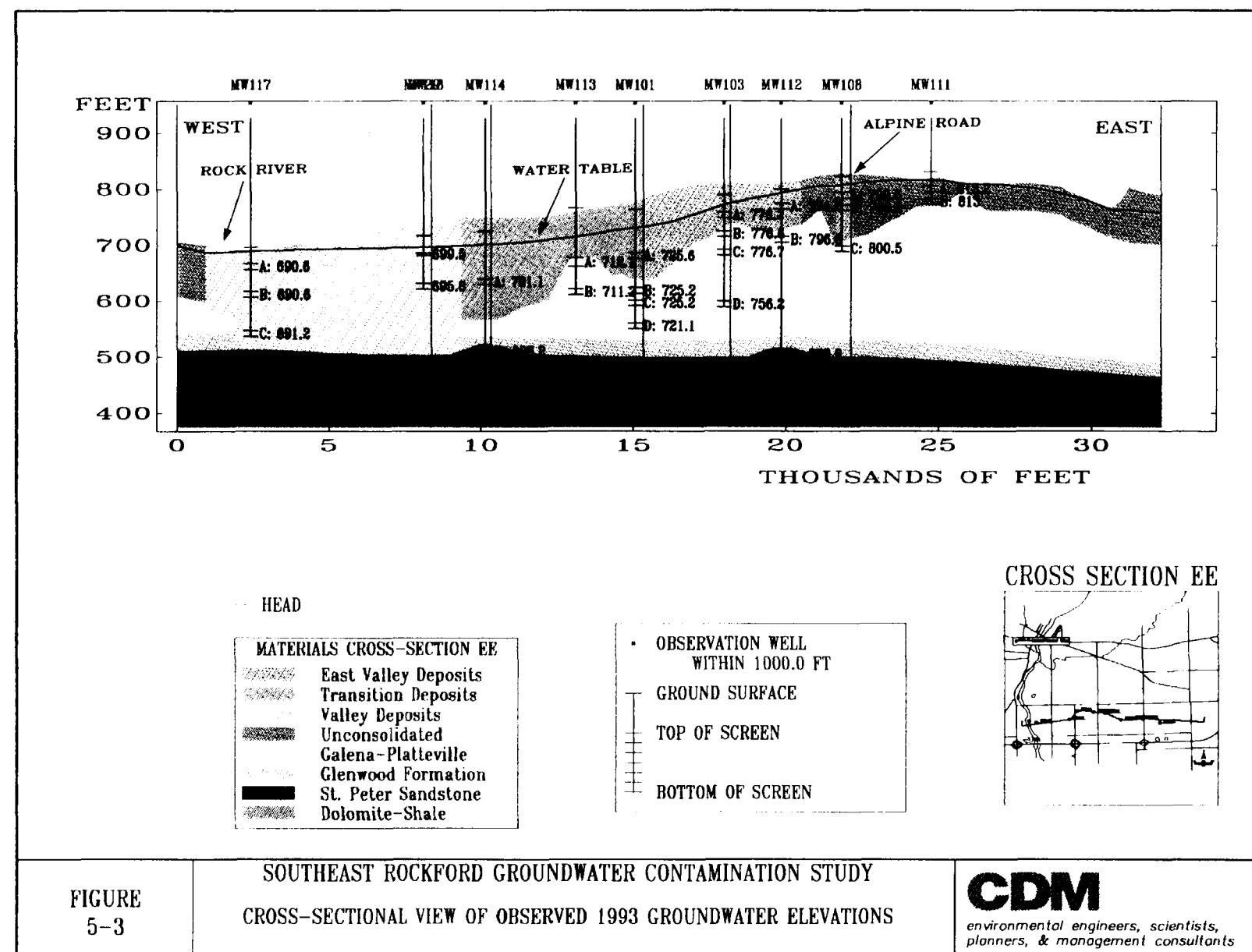


SCALE:

500 0 1000 Feet

VARIABLE CONTOUR INTERVAL 2, 5 OR 10 FEET

SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY
**GROUNDWATER ELEVATIONS IN THE
UNCONSOLIDATED AQUIFER, OCT. 26, 1993**



5.2.2 Observation Wells

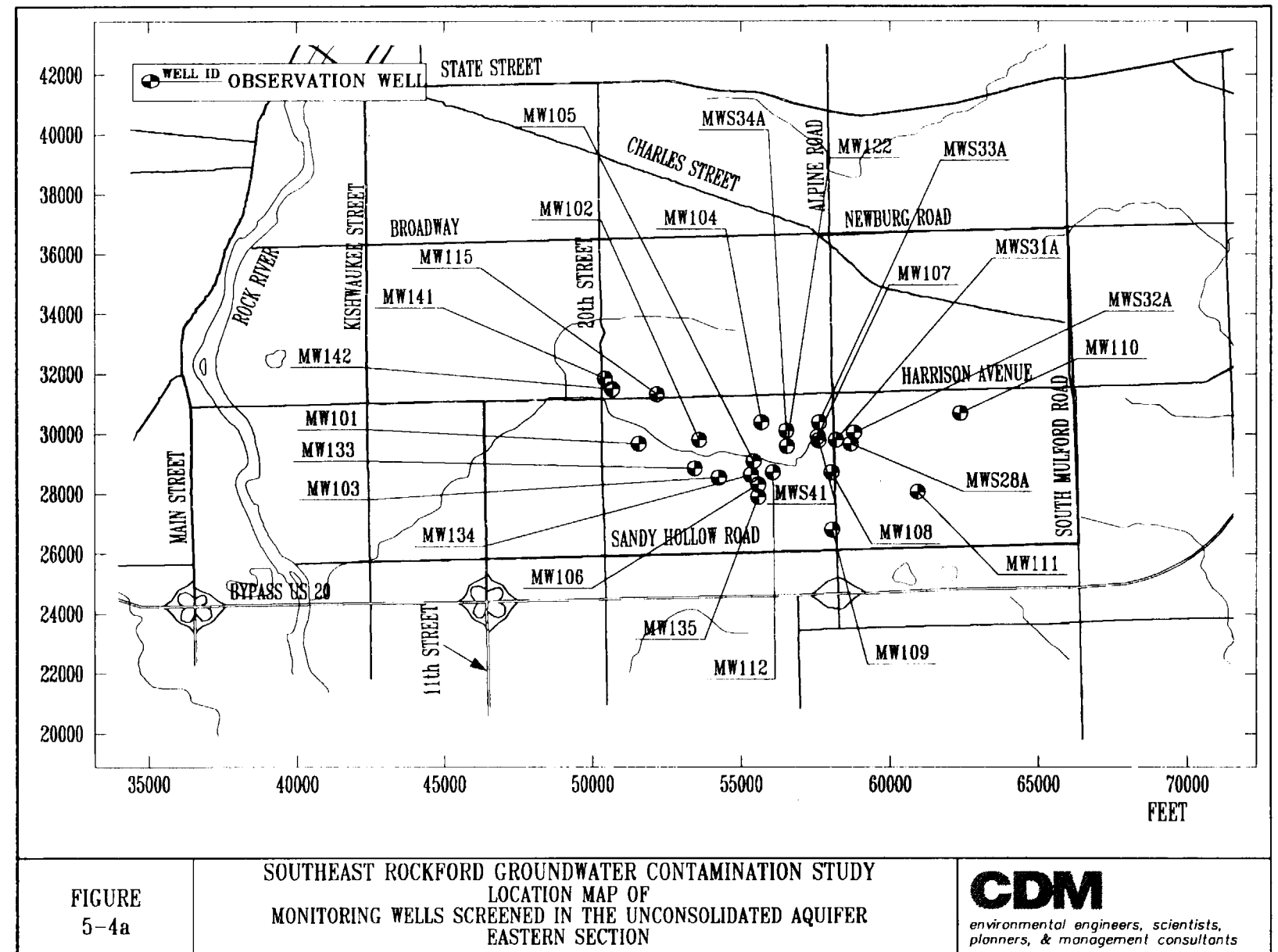
The observation well database for the groundwater model includes 79 monitoring wells installed by CDM/IEPA (includes two wells installed by the U. S. Geological Survey, MW101D and MW103D) and 28 wells that are part of the Illinois State Water Survey's (ISWS) network of wells in the study area. All of the ISWS wells and 54 of the CDM/IEPA wells were completed in the unconsolidated sediments; the remainder of the CDM/IEPA wells were installed in the Galena-Platteville dolomite (23) and St. Peter Sandstone (2). Further details about the CDM/IEPA monitoring wells are given in Section 2.0 of this report. In addition, 14 monitoring wells from the Sundstrand facility at the corner of Harrison Avenue and Alpine Road have been included in the observation well database. Figures 5-4a, 5-4b, and 5-5 show the locations of the observation wells screened in the unconsolidated sediments and bedrock units. The Sundstrand wells are labeled with a "MWS" prefix in Figures 5-4a and 5-5.

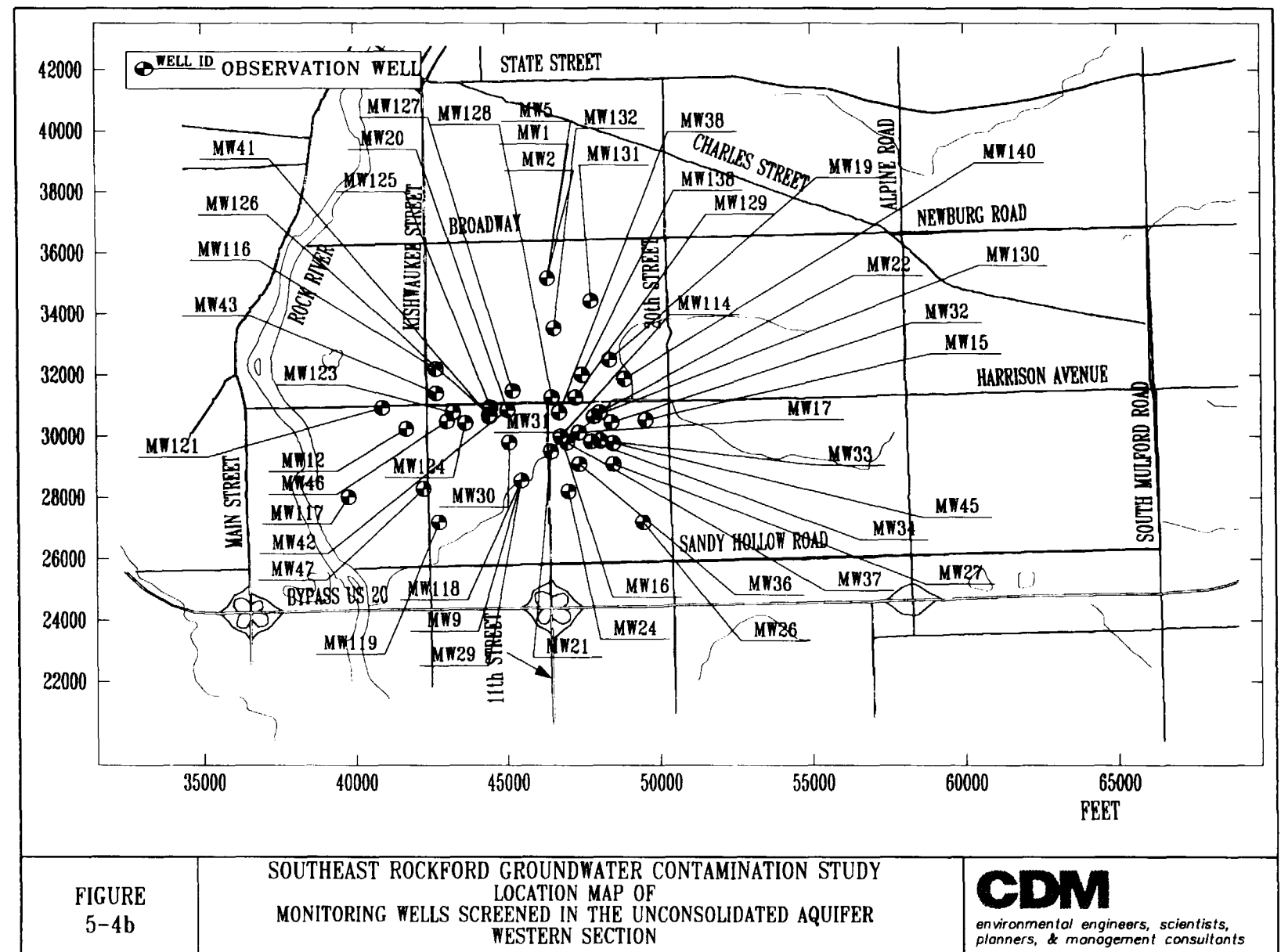
5.2.3 Pumping Wells

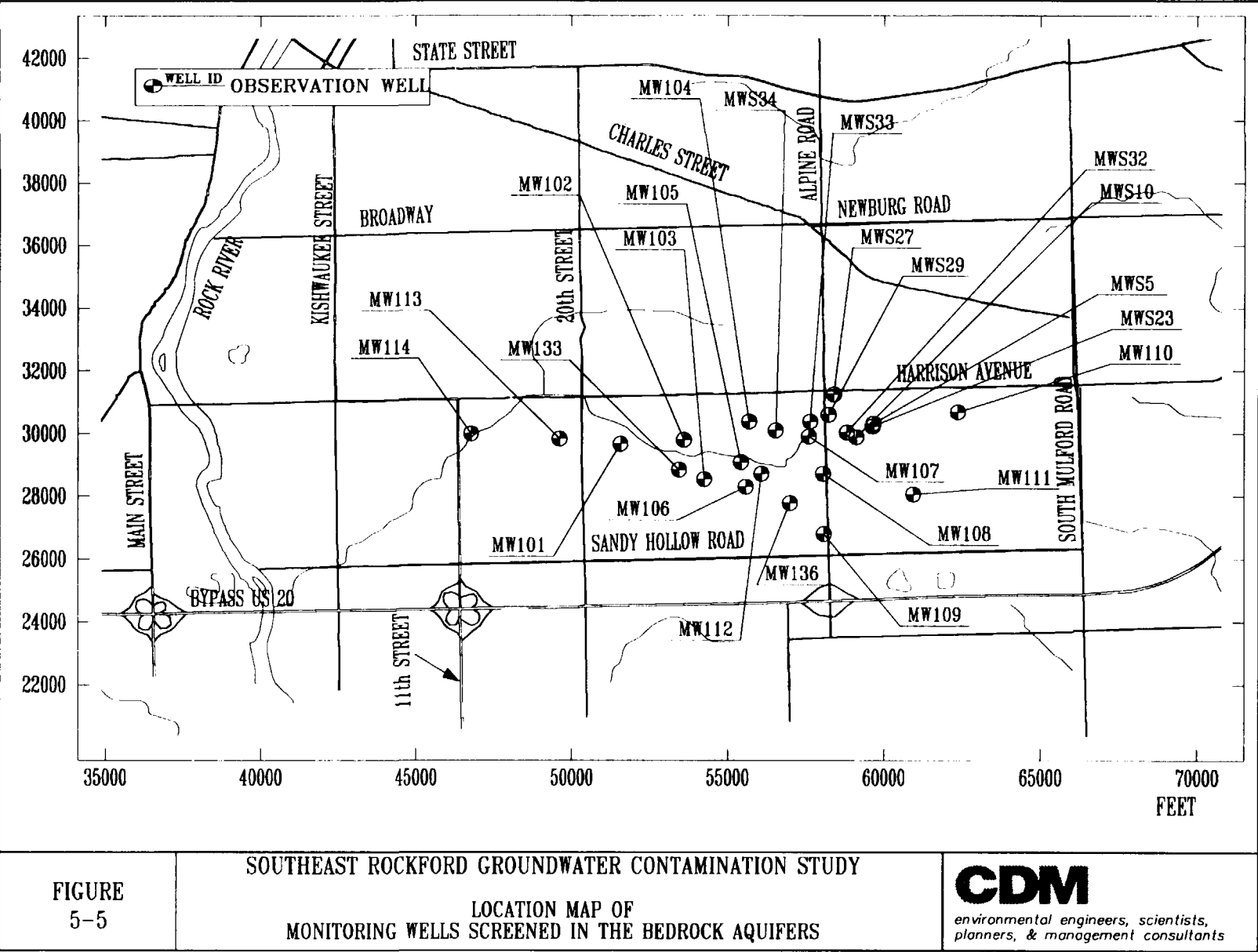
The city of Rockford has a large network of water supply wells (also referred to as Unit Wells) that provide groundwater for their drinking water supply. We have incorporated 38 wells in the modeled area into the well database for the groundwater flow model: 14 from the unconsolidated aquifer and 24 from bedrock aquifers. Bedrock Unit Wells typically are constructed as "open hole" from the St. Peter Sandstone (Layer 2) down to Cambrian sandstones in Layer 1, a stratigraphic interval typically exceeding 1,000 feet. The location of the Unit Wells is shown in Figures 5-6 and 5-7.

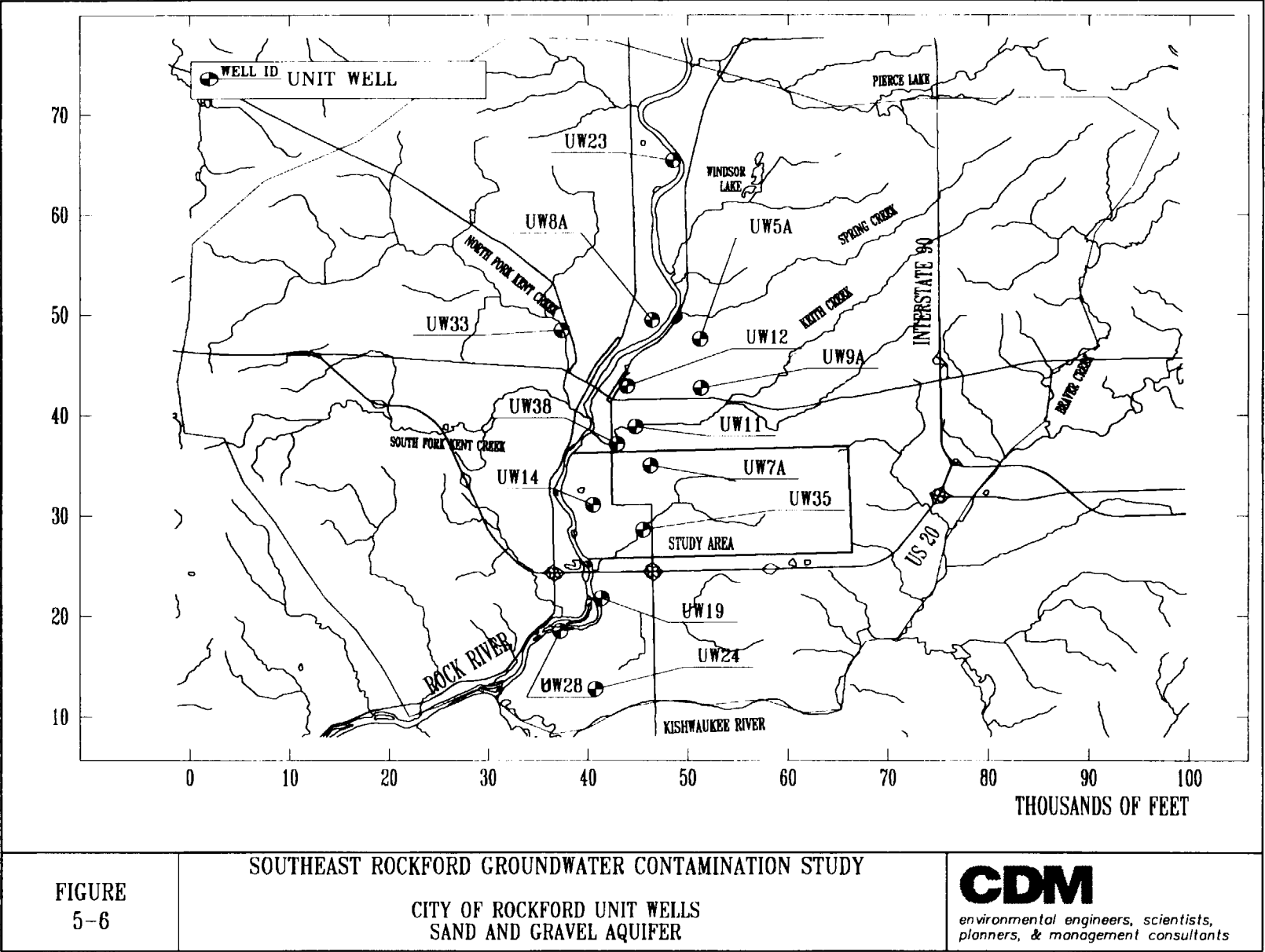
Annual pumping data for the Rockford Unit Wells has been incorporated into the groundwater model database. These data were provided by the Illinois State Water Survey for the 29-year period 1960 to 1988. Over this period, total pumpage varied from 7.2 to 13.2 billion gallons per year, with peak pumpage occurring in the early to mid-1970s. Pumping data for 1993 were obtained from the City of Rockford Water Division. Table 5-1 shows pumpage data used in developing the historical groundwater flow fields, discussed below in Section 5.6, and in calibrating the flow field.

Pumpage data for industrial wells were not available for this study. Available information indicates that industrial wells are probably screened in bedrock units and that these wells are primarily located near the Rock River (Visocky, 1993). Due to the depth of industrial pumping relative to that of significant contamination within the study area, and the presence of a confining unit (Glenwood Formation) over much of the model area, the lack of information on industrial pumping rates likely does not significantly diminish the predictive ability of the flow and transport model.









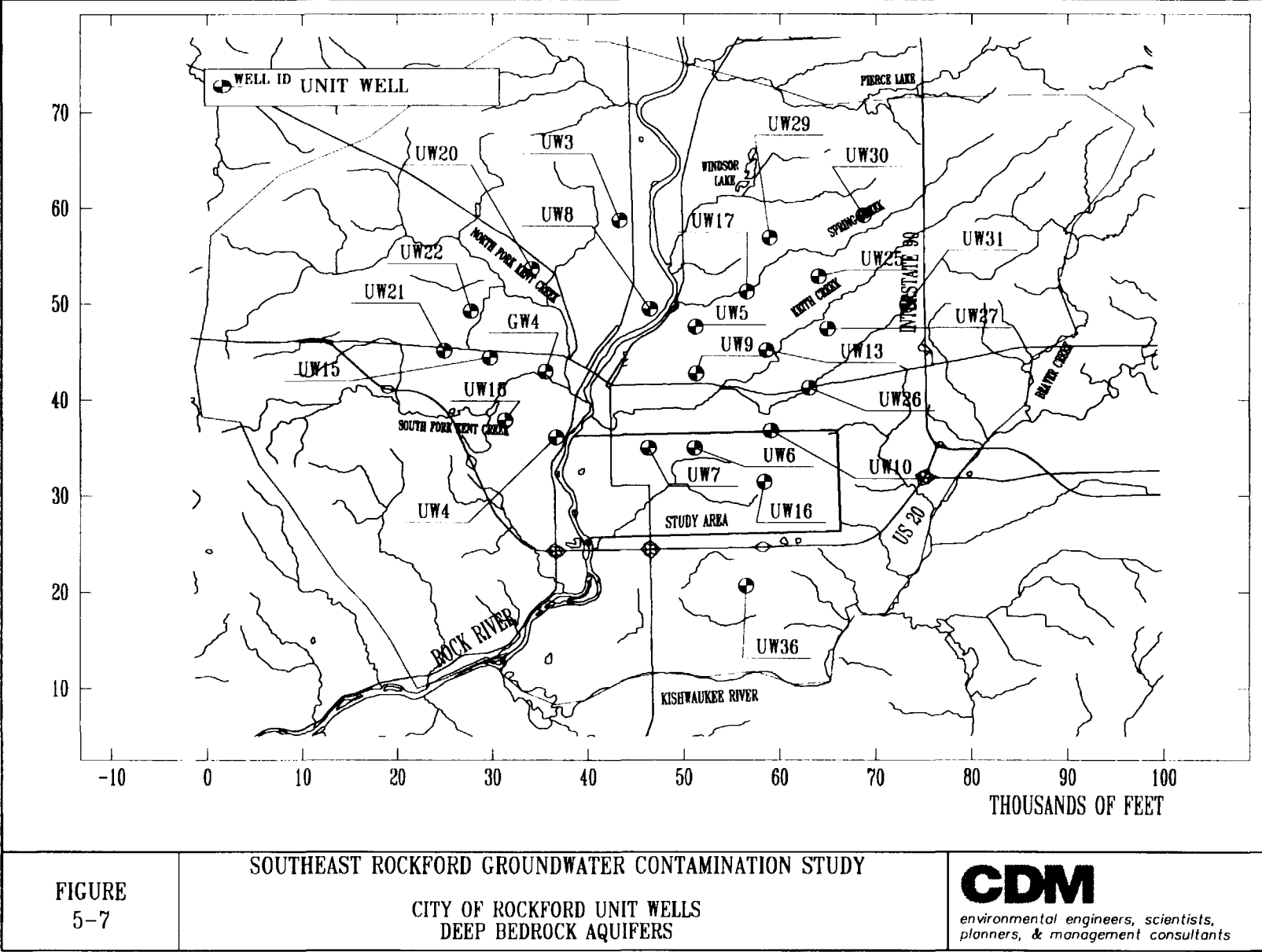


Table 5-1
Annual Pumping Data for Unit Wells

VOLUME PUMPED (in 1E+06 gal.)								
Unit Well	1960	1965	1970	1975	1980	1985	1988	1993
GW4	258.510	295.578	231.598	61.470	8.752	0.000	0.000	0.000
UW3	726.272	612.128	612.009	770.513	553.595	0.000	506.494	299.737
UW4	940.866	499.768	549.316	552.629	625.472	498.818	417.990	114.196
UW5	0.000	25.812	0.000	88.124	505.670	563.194	290.139	300.071*
UW5A	0.000	65.313	0.000	0.000	0.000	375.463	354.615	300.071*
UW6	19.132	0.000	210.698	3.567	0.000	0.000	499.206	334.021
UW7	425.374	148.166	601.355	852.408	0.000	0.000	0.000	0.000
UW7A	943.538	840.244	640.442	495.383	1441.302	2.203	0.000	0.000
UW8	0.000	26.244	222.969	0.000	0.000	0.000	0.000	0.000
UW8A	0.000	190.052	908.550	340.108	359.803	0.000	0.000	0.000
UW9	0.000	122.240	19.662	0.000	0.000	0.000	0.000	0.000
UW9A	0.000	607.266	80.581	476.677	474.161	342.145	615.619	421.039
UW10	0.000	93.069	506.927	372.698	282.393	335.475	474.404	191.706
UW11	1096.153	1170.819	887.284	580.307	692.362	573.111	421.151	293.444
UW12	237.704	841.127	743.102	283.869	450.813	416.520	761.812	184.348
UW13	319.691	402.951	248.286	355.249	191.346	214.497	0.000	0.000
UW14	1067.730	12.896	377.348	0.000	0.000	0.000	0.000	0.000
UW15	18.316	291.175	170.901	166.741	73.147	194.581	81.692	135.930
UW16	310.073	516.213	489.868	327.940	351.860	400.772	87.109	139.973
UW17	0.000	366.133	51.373	294.453	347.357	220.704	343.286	283.977
UW18	0.000	87.827	412.395	351.427	124.652	0.000	397.628	215.264
UW19	1.295	969.778	221.082	0.000	0.000	0.000	0.000	0.000
UW20	0.000	0.000	211.939	337.535	440.113	240.436	262.795	329.298
UW21	0.000	0.000	530.478	212.291	389.987	320.245	429.644	333.168
UW22	0.000	920.893	539.183	283.233	140.619	359.262	238.391	335.658
UW23	0.000	0.000	120.260	174.101	148.675	760.371	569.282	382.059
UW24	0.000	0.000	725.366	855.452	743.386	6.779	168.584	426.803
UW25	0.000	0.000	873.409	703.001	411.452	340.042	497.780	199.601
UW26	0.000	0.000	546.118	909.304	668.619	781.974	538.111	258.601
UW27	0.000	0.000	9.110	633.965	272.209	149.834	321.275	185.320
UW28	0.000	0.000	105.303	50.366	232.072	762.909	499.100	166.845
UW29	0.000	0.000	0.000	0.000	0.000	394.185	415.399	234.442
UW30	0.000	0.000	0.000	162.743	255.569	479.335	447.128	234.086
UW31	0.000	0.000	0.000	0.000	0.000	614.745	651.119	391.501
UW33	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UW35	0.000	0.000	0.000	449.870	560.990	255.673	14.760	223.673
UW36	0.000	0.000	0.000	951.982	223.467	368.127	316.113	75.495
UW38	0.000	0.000	0.000	316.921	420.493	72.086	0.000	0.000
TOTAL	6364.654	9105.692	11846.912	12414.327	11390.336	10043.486	10620.626	6390.185

*Assumed that each well pumped one-half the total volume of 600.142 million gallons in 1993
Pumping data obtained from Illinois State Water Survey, except 1993 obtained from City of Rockford Water Division

5.3 Groundwater Modeling Code

The governing equation for three-dimensional groundwater flow is:

$$S_s \frac{\partial \Phi}{\partial t} = \frac{\partial (K_{ij} \frac{\partial \Phi}{\partial x_j})}{\partial x_i} \quad i, j = 1, 3 \tag{1}$$

where the state variable, Φ , represents the piezometric head; K_{ij} represents the hydraulic conductivity in the principal directions in an orthogonal reference frame; S_s is the specific storativity (or specific yield under phreatic conditions); s_i is a Cartesian coordinate, and t is time.

The model of groundwater flow that was used in this study is CDM's fully three-dimensional, dynamic finite element code, DYNFLOW, which solves the above equation numerically. DYNFLOW uses triangular elements in plan view. Within each level of the model, an identical plan grid is used, but the thickness of each model layer (vertical distance between levels in the model) can vary at each point in the grid. Figure 5-8 illustrates the resulting vertical triangular prism, showing the 3-dimensional discretization.

DYNFLOW uses various types of boundary conditions on the groundwater flow system, including:

- fixed head boundaries (lakes, rivers, well locations)
- specified flux boundaries (rainfall, infiltration, pond leakage, no flow streamlines)
- rising water boundaries that are hybrid boundaries (specified head or specified flux depending on the system status).

The DYNFLOW code has been reviewed by the International Groundwater Modeling Center (van der Heijde, 1985).

5.4 Description of Model

5.4.1 Modeled Area and Study Area

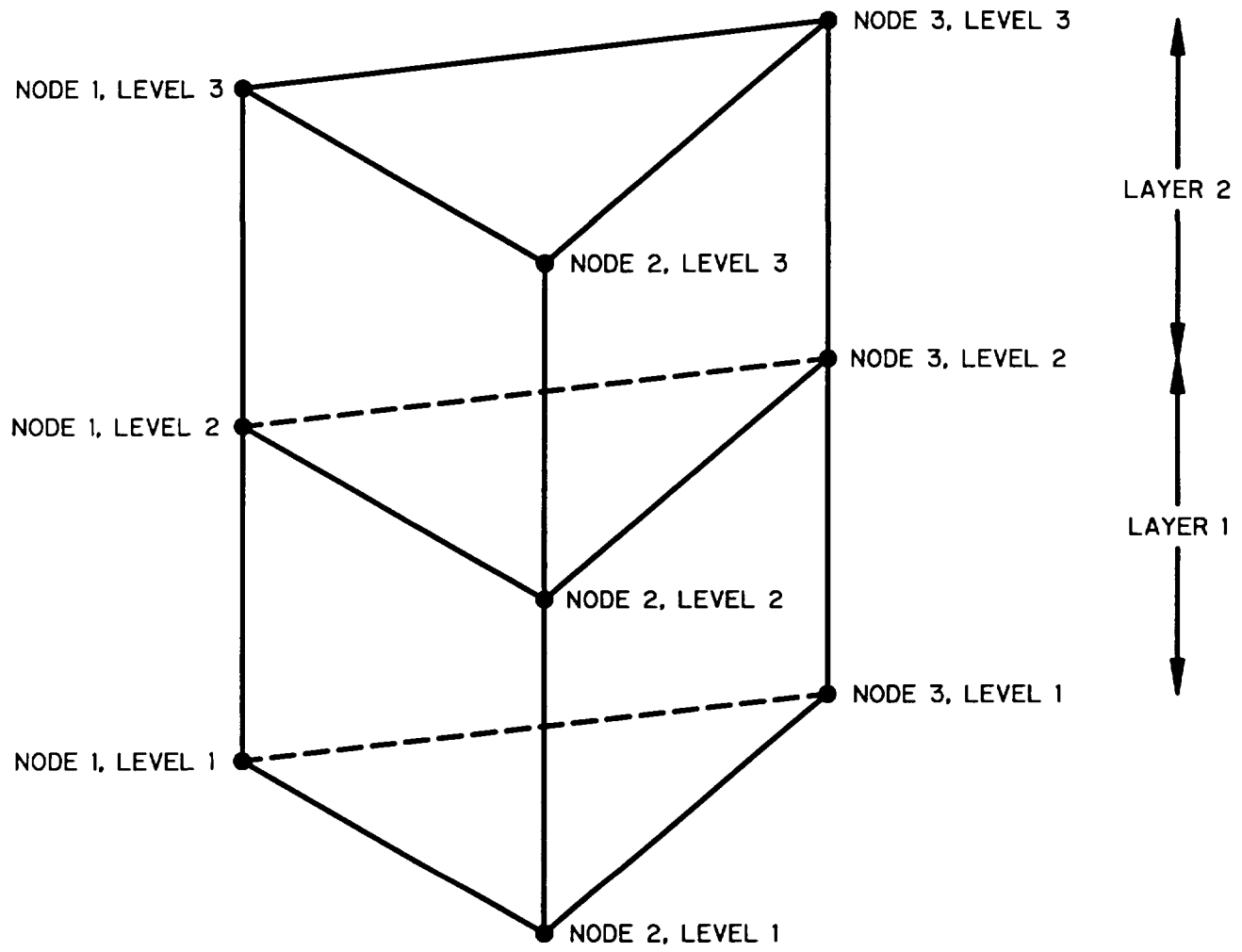
Figure 5-9 shows the finite element grid used in the model along with major geographic features and roads. The finite element grid covers 170 square miles and contains 1095 nodes in each of its six levels. Grid boundaries were chosen to coincide with either surface water divides, which generally indicate the location of groundwater divides, or major surface water features that are located far from the study area. The reason for choosing grid boundaries an adequate distance from the area of interest is to minimize the influence of boundary conditions on the simulated results within the study area. As shown in Figure 5-9, the northeast corner and western half of the grid boundary lie along surface water divides identified on topographic maps; the remainder of the grid boundary follows major surface water bodies. Note that the area with greater grid

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FIG5-8

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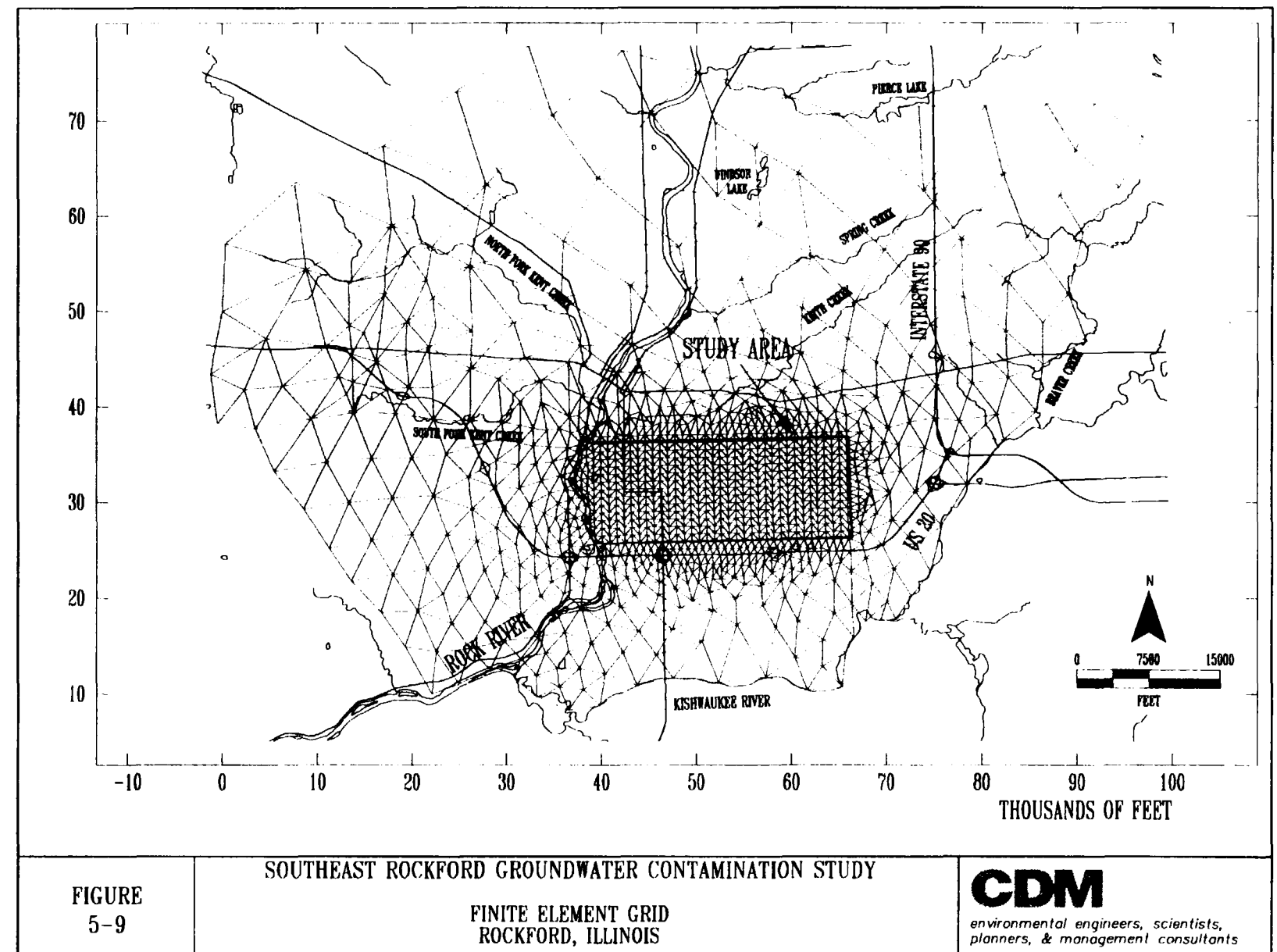


SOUTHEAST ROCKFORD
GROUNDWATER CONTAMINATION STUDY

DYNFLOW WORKING ELEMENT

CDM
environmental engineers, scientists,
planners, & management consultants

FIGURE 5-8



density in Figure 5-9 corresponds to the study area for the Southeast Rockford Groundwater Contamination Study. Details of the study area are shown in Figure 5-10. The study area is bounded by the Rock River, Sandy Hollow Road, South Mulford Road, and Broadway.

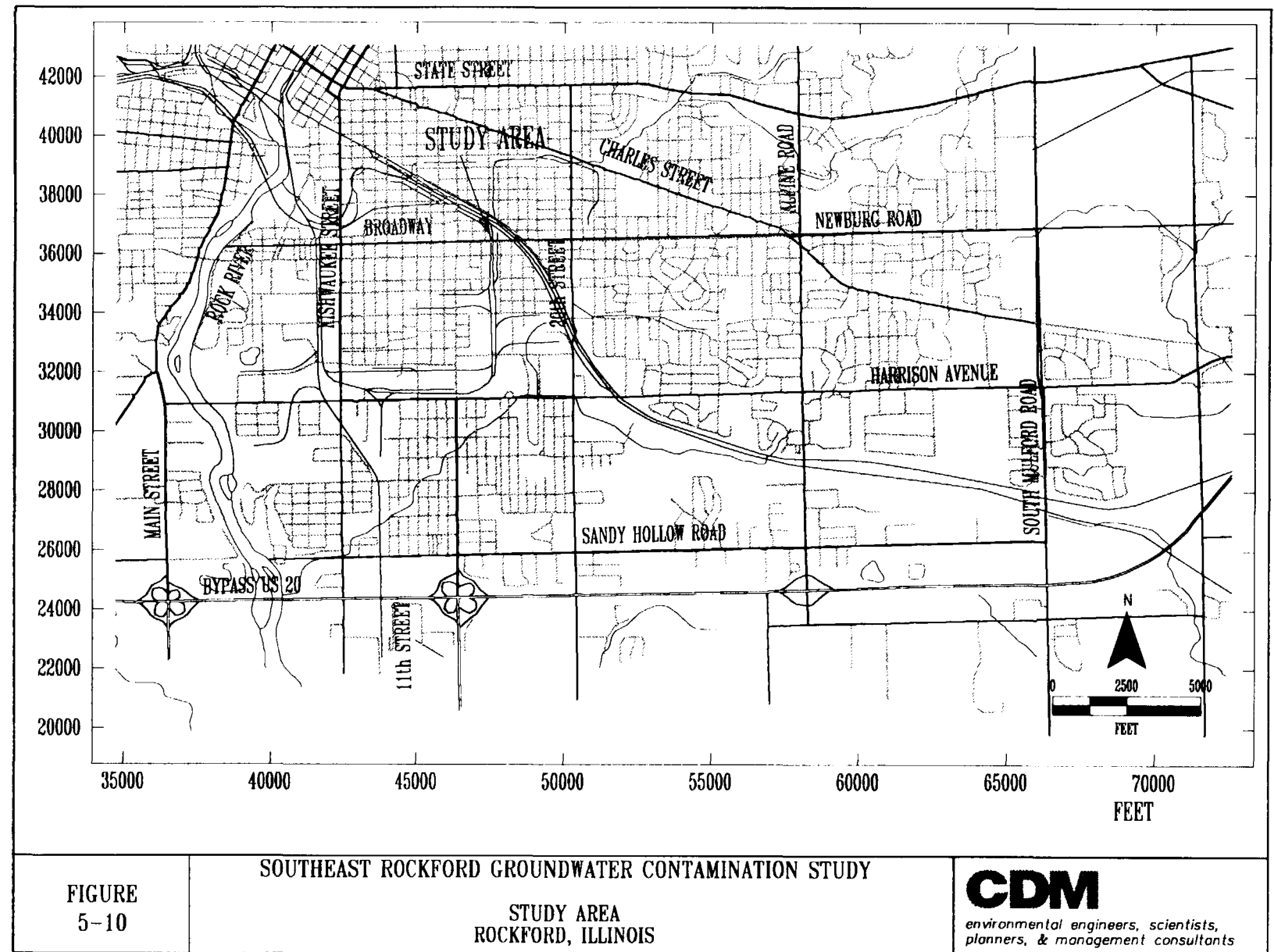
5.4.2 Model Stratigraphy

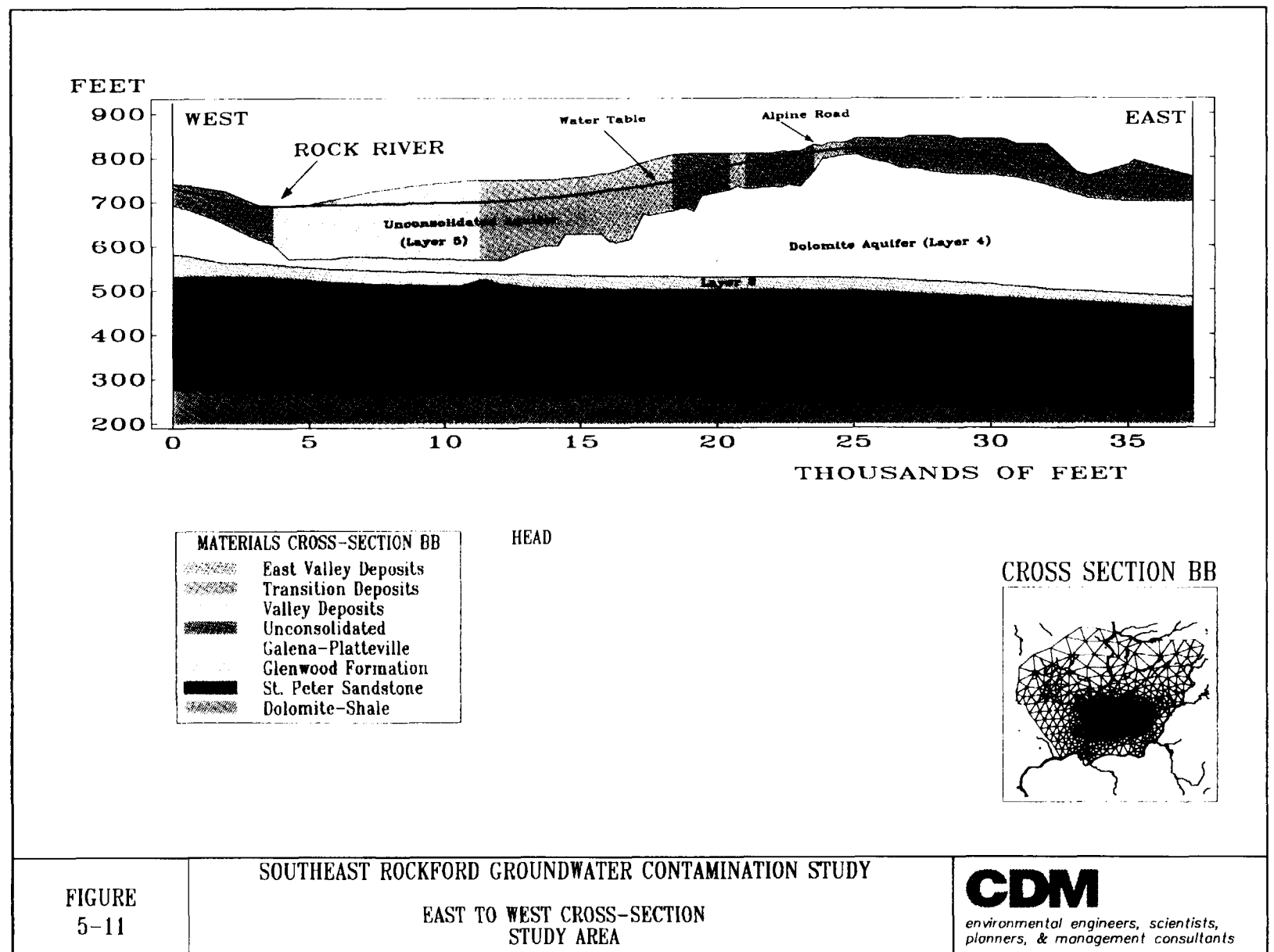
The stratigraphic units incorporated into the groundwater flow model include those previously discussed in Section 3.0 of this report. Figure 5-11 shows a representative east to west cross section through the study area. Additional details of regional stratigraphy and aquifer groups can be found in Willman et al. (1975) and Visocky et al. (1985).

A total of five stratigraphic layers were included in the model. The convention employed in DYNFLOW is to number the strata starting with Layer 1 as the lowest layer. Layer 1 (labeled "Dolomite-Shale" in Figure 5-11) is 2,200-foot thick sequence of interbedded dolomite, sandstone, and shale that rests on Precambrian granite. In the model, the granite is assumed to be impermeable. Layer 1 incorporates as a single anisotropic unit the Mt. Simon Formation (Cambrian sandstone), Eau Claire Formation (Cambrian shale and siltstone), Ironton-Galesville Sandstone (Cambrian), Franconia Formation (Cambrian, mixed dolomite, sandstone, and shale), and the Eminence Formation and Potosi Dolomite (Cambrian dolomites). The Franconia and Eminence-Potosi formations are regional confining units; the Mt. Simon Formation and Ironton-Galesville Sandstones are important regional aquifers. The stratigraphic units composing Layer 1 have been included in the model because they are penetrated by the city of Rockford's pumping wells described earlier in this section. Combining the Cambrian units into a single layer is reasonable because less detail is required for these deep layers than for the overlying units in which contamination is of major concern. Note that the base of Layer 1 has been omitted from Figure 5-11 to emphasize the vertical detail in the overlying layers. Figure 5-8 illustrates the relationship between model layers and levels.

Model Layer 2 consists of the St. Peter Sandstone (Ordovician), an important potable water aquifer in northern Illinois and southern Wisconsin. The St. Peter Sandstone is a predominantly quartz sandstone that has an average thickness of about 270 feet in northern Illinois. The St. Peter is hydrologically similar to the Ironton-Galesville Sandstones included in Layer 1. Note that some regional studies combine the St. Peter and Glenwood as the Ancell Group (Visocky, 1993); however, they are separated in the model because of observed head differences.

Layer 3 represents the Glenwood Formation (Ordovician), composed of interbedded dolomite, sandstone, and shale, with the shale unit occurring at the top of the formation. At one Phase II drilling location, the top shale unit (Harmony Hill Shale Member) is approximately 5 feet thick and the total thickness of the Glenwood Formation is 24 feet. Available information from well logs for the city of Rockford's Unit Wells suggest that the Glenwood's thickness averages about 30 feet in the modeled area. Although it is not noted to be a confining unit on a regional scale, the measured head difference of approximately 100 feet across the Glenwood Formation suggests that the Glenwood is a confining layer within portions of the study area. Within the deeper parts of the preglacial Rock Bedrock Valley, located just east of the present-day Rock River, erosion has removed the Glenwood Formation and the overlying Galena-Platteville dolomite,





leaving the St. Peter Sandstone as the uppermost bedrock unit encountered beneath the unconsolidated sediments. Thus, in these areas Layer 3 represents the unconsolidated Valley Deposits. It is likely that the Glenwood Formation is present in limited quantities within the bedrock valley; however, well logs examined for this study typically either include the Glenwood as part of the St. Peter, or combine both units as the Ancell Group. It is assumed that the Harmony Hill Shale Member of the Glenwood Formation is present where both the Galena-Platteville Group and the St. Peter Sandstone are present. Figure 5-12 shows the Rock Bedrock Valley in plan view.

In the upland areas Layer 4 is the Galena-Platteville Group (Ordovician), a dolomite unit that underlies the unconsolidated glacial sediments across most of the modeled area. The Galena-Platteville is a fractured unit; however, in the model it is treated as an equivalent porous medium. In the Rock Bedrock Valley it is assumed that the St. Peter is the first bedrock unit encountered at locations where the Galena-Platteville is not present. Thus, in these areas Layer 4 represents the unconsolidated Valley Deposits.

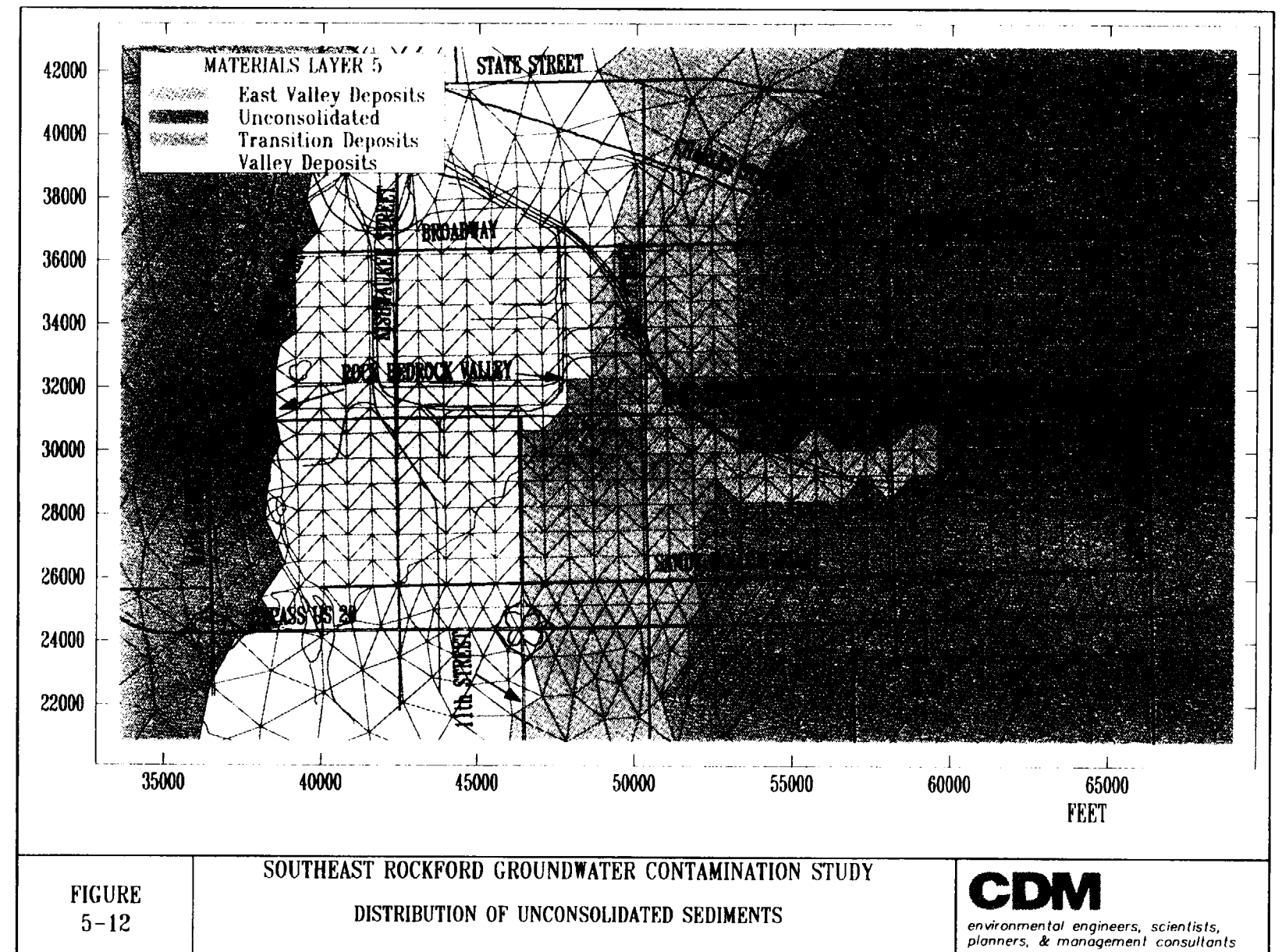
Layer 5 is composed of unconsolidated Pleistocene sediments deposited during the Illinoian and Wisconsin glacial events. These sediments include a complex assemblage of glacial tills, outwash sand and gravel, and ice-contact deposits (Berg et al., 1984). Within the modeled area, the thickness of the unconsolidated sediments varies from less than 20 feet in upland areas to over 150 feet in the preglacial bedrock valleys.

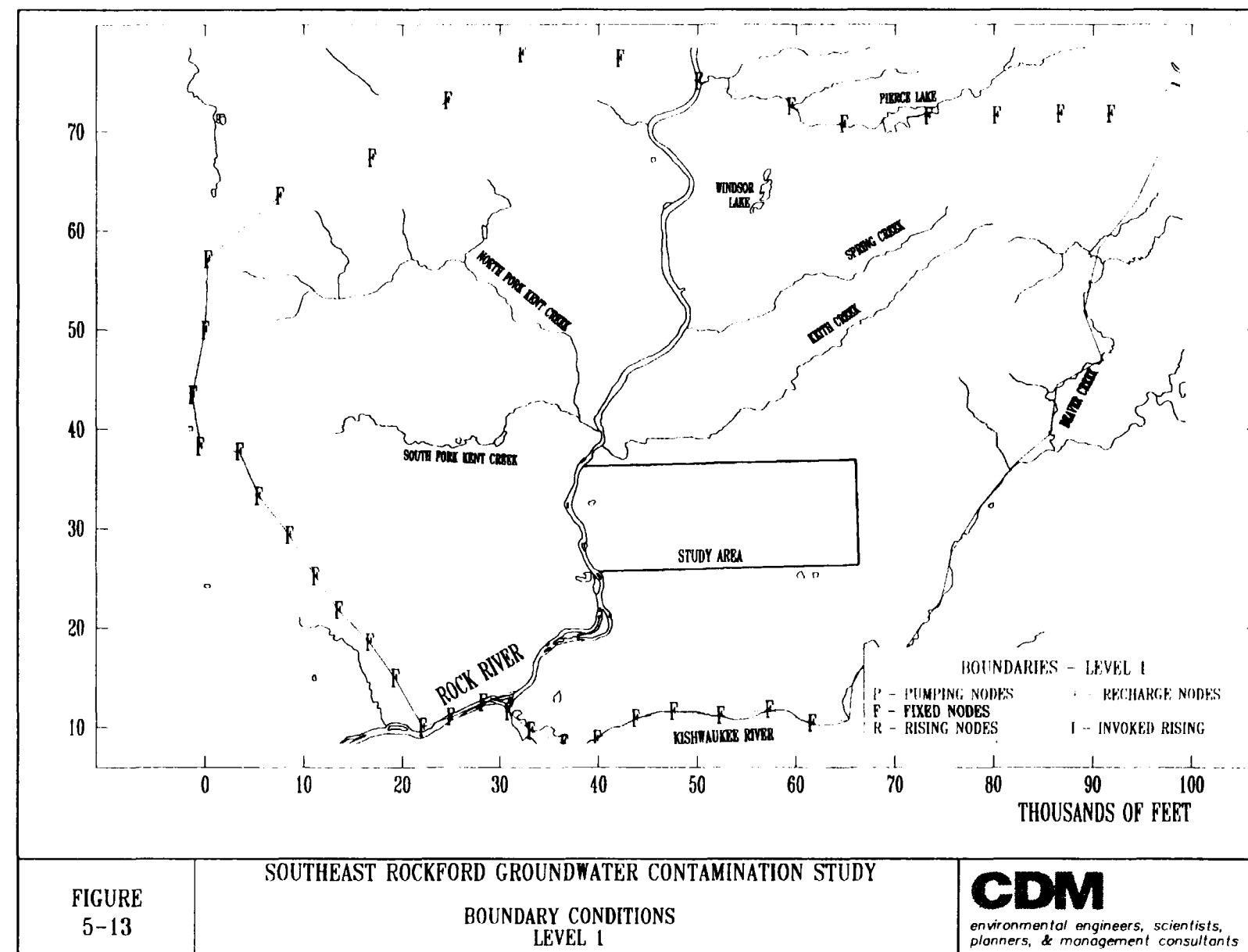
The distribution of materials in Layer 5 is shown in Figure 5-12. The Valley Deposits are primarily sand and gravel sediments fluvially deposited in the ancient Rock Bedrock Valley. The East Valley Deposits were deposited in a tributary valley to the Rock Bedrock Valley, primarily by fluvial processes, although parts of the east valley contain both till and sand and gravel layers (see Section 3.0 of this report). This is particularly true near the eastern margin of the East Valley Deposits. The Transition Deposits were incorporated into the model during calibration of the flow field when the need for material with intermediate hydraulic properties became apparent.

5.4.3 Boundary Conditions

Natural topographic features and regional and local hydrological information were used to assign boundary conditions for the model. For Levels 1 through 3 (bottom of Layer 1 through top of Layer 2, representing the deeper bedrock aquifers), nodes along the east boundary of the grid were assigned no-flow conditions because studies have identified a regional groundwater divide at depth (Layers 1 and 2) located approximately 12 miles to the east of the modeled area (Sasman et al., 1982; Visocky, 1993). On other boundaries in Layers 1 and 2, heads were specified at values derived from regional potentiometric surface maps. The bottom surface of Layer 1 was also given no-flow conditions because the basal sandstone rests on impermeable Precambrian granite. Figure 5-13 shows the location of specified head conditions (indicated by the "F" symbol) for Level 1.

For Levels 4 through 6 (bottom of Layer 4 through top of Layer 5, representing the dolomite and unconsolidated aquifers), the west boundary of the grid was assigned no flow conditions because





it occurs along a surface water divide and a groundwater divide for the shallow aquifers. Nodes along the east boundary were specified at surface water elevations. In addition, heads along the Rock River, Kishwaukee River, and Beaver Creek in Level 6 were specified at the surface water elevation. Specified head conditions were also assigned to ponds located in Level 6 southeast of Alpine and Sandy Hollow Roads because of the potential influence on heads at nearby observation wells. The ground surface (Level 6) of the model was specified as a conditional ("rising water") boundary, meaning that if the simulated water table is below the ground surface, then a no-flow boundary is specified. Conversely, if the simulated water table is above the ground surface, then the head is specified at the ground elevation and an outward flux is computed. Figure 5-14 shows the location of specified head conditions for Level 6. Uniform surficial recharge of 15 in/yr for the Valley Deposits and 10 in/yr for all other surficial zones were assumed. The model's ability to reasonably reproduce flow conditions using hydraulic conductivity values consistent with field test values strengthens confidence in the validity of this assumption.

5.5 Calibration of Steady State Flow Field

Calibration is the process of refining the modeled hydraulic properties to reasonably reproduce the measured characteristics that define the groundwater flow field. The purpose of calibration is to verify that the model is able to simulate existing conditions using reasonable estimates of hydraulic conductivity. A properly calibrated system is essential to the model's predictive capability. A steady state calibration was done for the Southeast Rockford site.

In calibrating the steady state flow model discussed below, it is assumed that the modeled system represents an equilibrium condition not influenced by long-term transients due to unmodeled stresses. Existing stresses, such as pumping, which have been incorporated in the model, are therefore sufficient to account for the heads in the calibrated model.

5.5.1 Steady State Calibration

The October 26, 1993 round of head measurements was used for the steady state calibration. The initial estimates of horizontal and vertical conductivity used in the model were based on various field tests, which are discussed in sections 2 and 3 of this report, or on values taken from the technical literature. During the calibration these values were adjusted so that the model as a whole reasonably reproduced the observed horizontal and vertical gradients, and minimized spatial bias in the difference between the simulated and observed heads. In the calibrated flow model, average 1993 pumping rates (see Table 5-1) were assigned to the node located nearest each pumping well. Pumping was distributed vertically by assuming that flow was drawn uniformly from each layer spanned by the well screen. Unrealistically large simulated drawdowns were initially observed in the Galena-Platteville and unconsolidated aquifers at pumping well UW6 because it is open to the lower 27 feet of the Galena-Platteville dolomite. Accordingly, pumping was redistributed vertically so that the flow removed from each layer spanned by the well was proportional to the relative transmissivity of the unit.

Table 5-2 presents the hydraulic properties developed during the calibration process. Horizontal hydraulic conductivity values for the St. Peter Sandstone, Galena-Platteville, and the

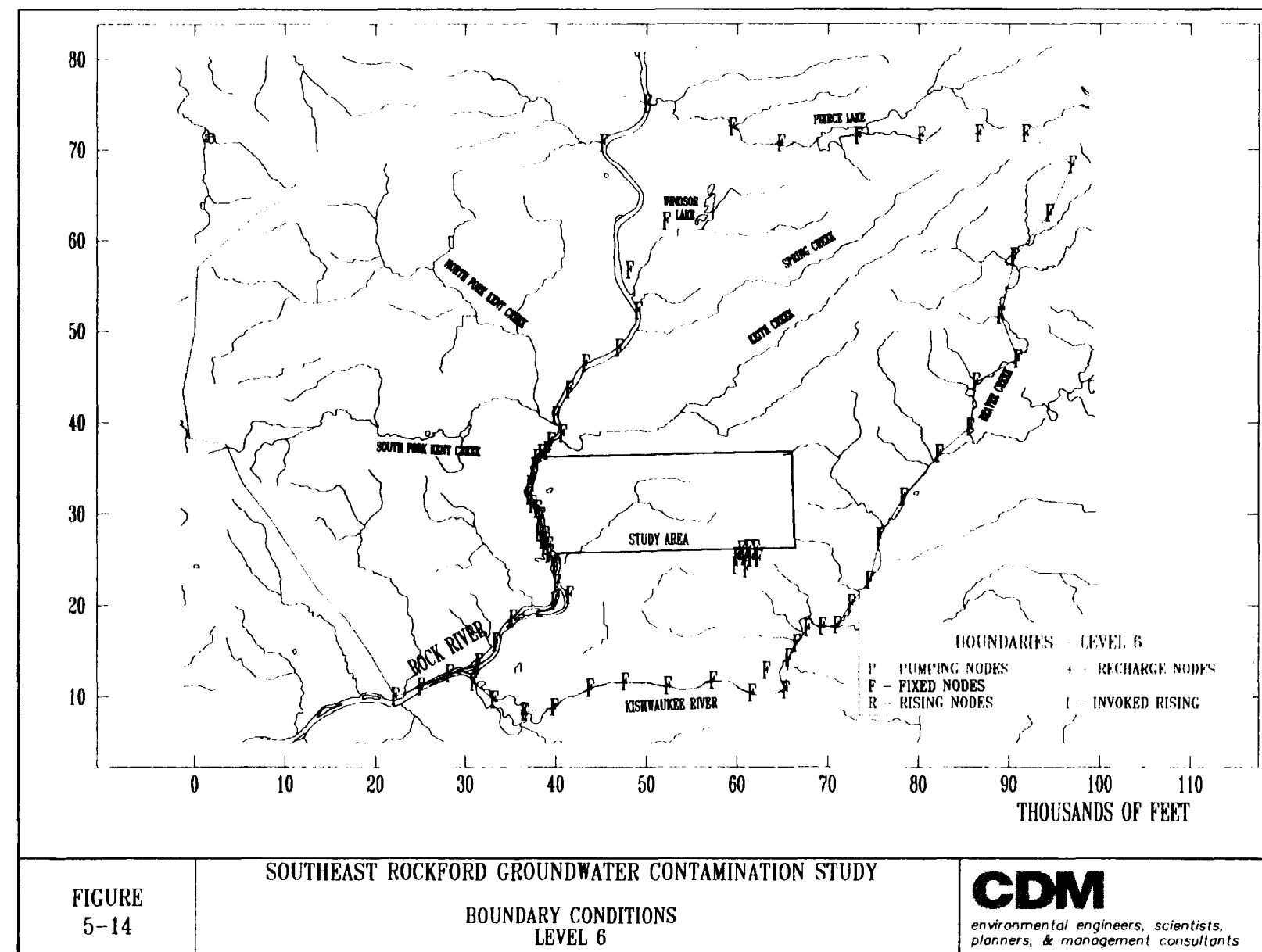


Table 5-2
Hydraulic Properties for Calibrated Model

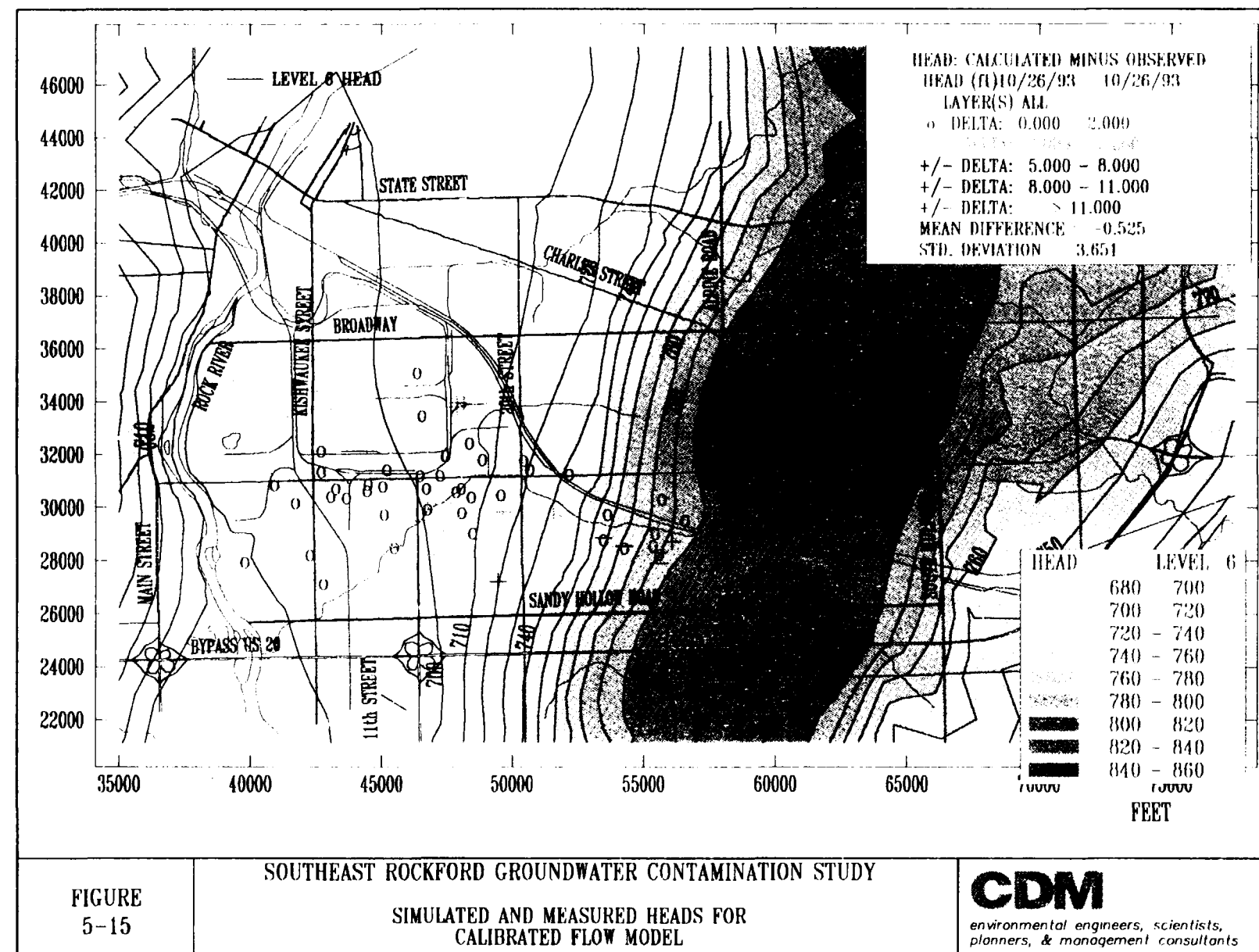
MATERIAL	LAYER	LAYER NAME	Hydraulic Conductivity (ft/day)	
			Horizontal (Kxx, Kyy)	Vertical (Kzz)
10	1	Dolomite-Shale	10.00	0.001
20	2	St. Peter Sandstone	10.00	0.001
30	3	Glenwood Formation	0.10	9.50E-05
31	3	Valley Deposits	130.00	1.500
40	4	Galena-Platteville	3.50	4.00E-03
41	4	Valley Deposits	130.00	1.500
50	5	Unconsolidated	7.00	0.2500
51	5	Valley Deposits	130.00	1.500
52	5	East Valley Deposits	8.00	0.1500
53	5	Transition Deposits	45.00	0.3000

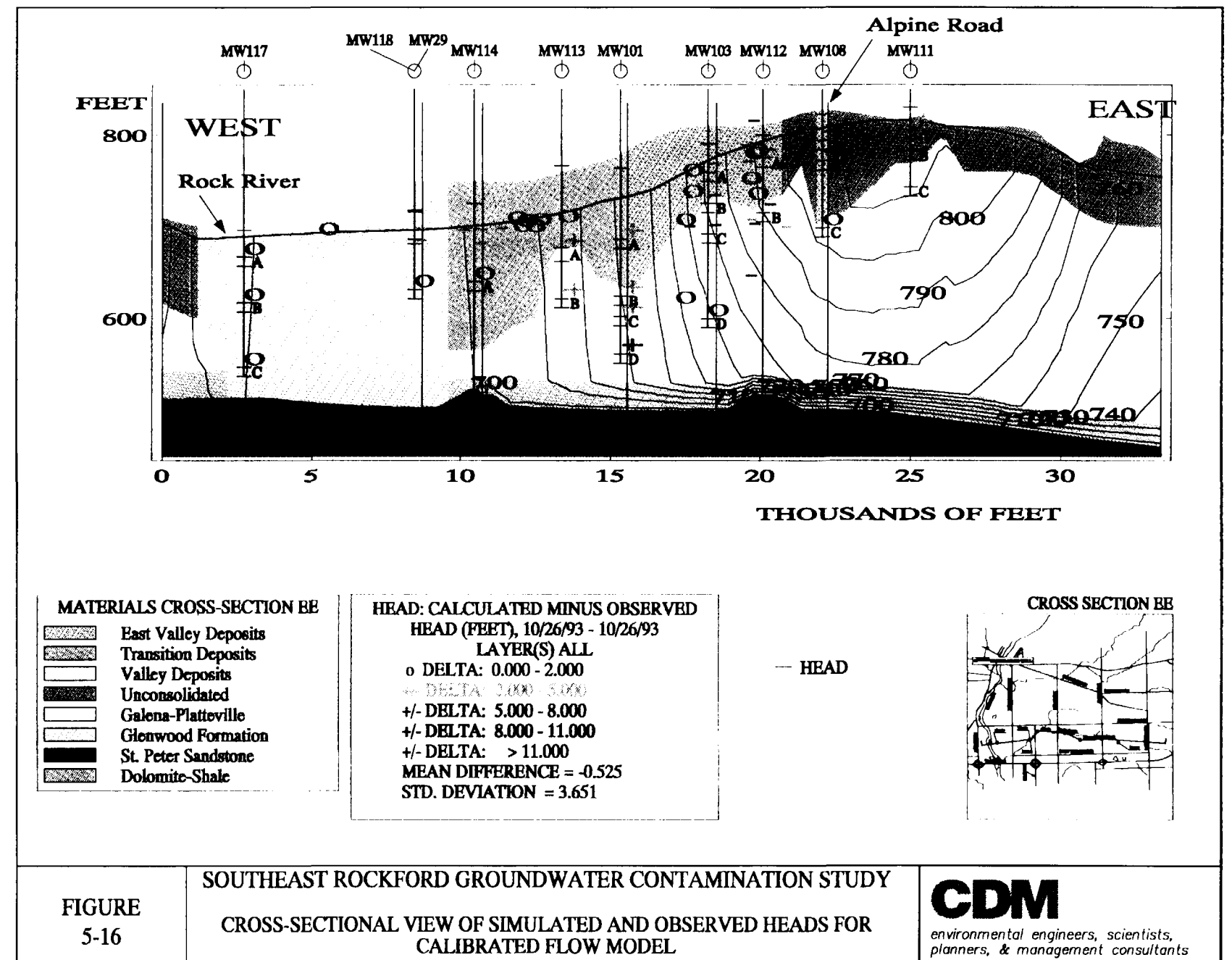
unconsolidated layers are in good agreement with measured values previously discussed in Section 3.0. Valley Deposit values are consistent with pump test data suggesting that hydraulic conductivities in this portion of the unconsolidated aquifer exceed 100 feet/day (Wehrmann et al., 1988). Conductivity values for Transition Deposits are somewhat higher than the geometric mean of measured values presented in Section 3.0. Note that the slug test data represent measurements from spatially isolated points and may not accurately reflect the overall permeability of the aquifer. Hydraulic conductivities for the Glenwood Formation and the Dolomite-Shale layers are reasonable for the lithologies they represent. It should be noted that heads in the unconsolidated unit (Layer 5) and the Galena-Platteville dolomite are sensitive to the vertical hydraulic conductivity (K_{zz}) of the Glenwood Formation. During the calibration process, K_{zz} for the Glenwood Formation and the horizontal hydraulic conductivity (K_{xx} and K_{yy}) for the overlying units were varied simultaneously to obtain the appropriate vertical gradients and vertical and horizontal velocities.

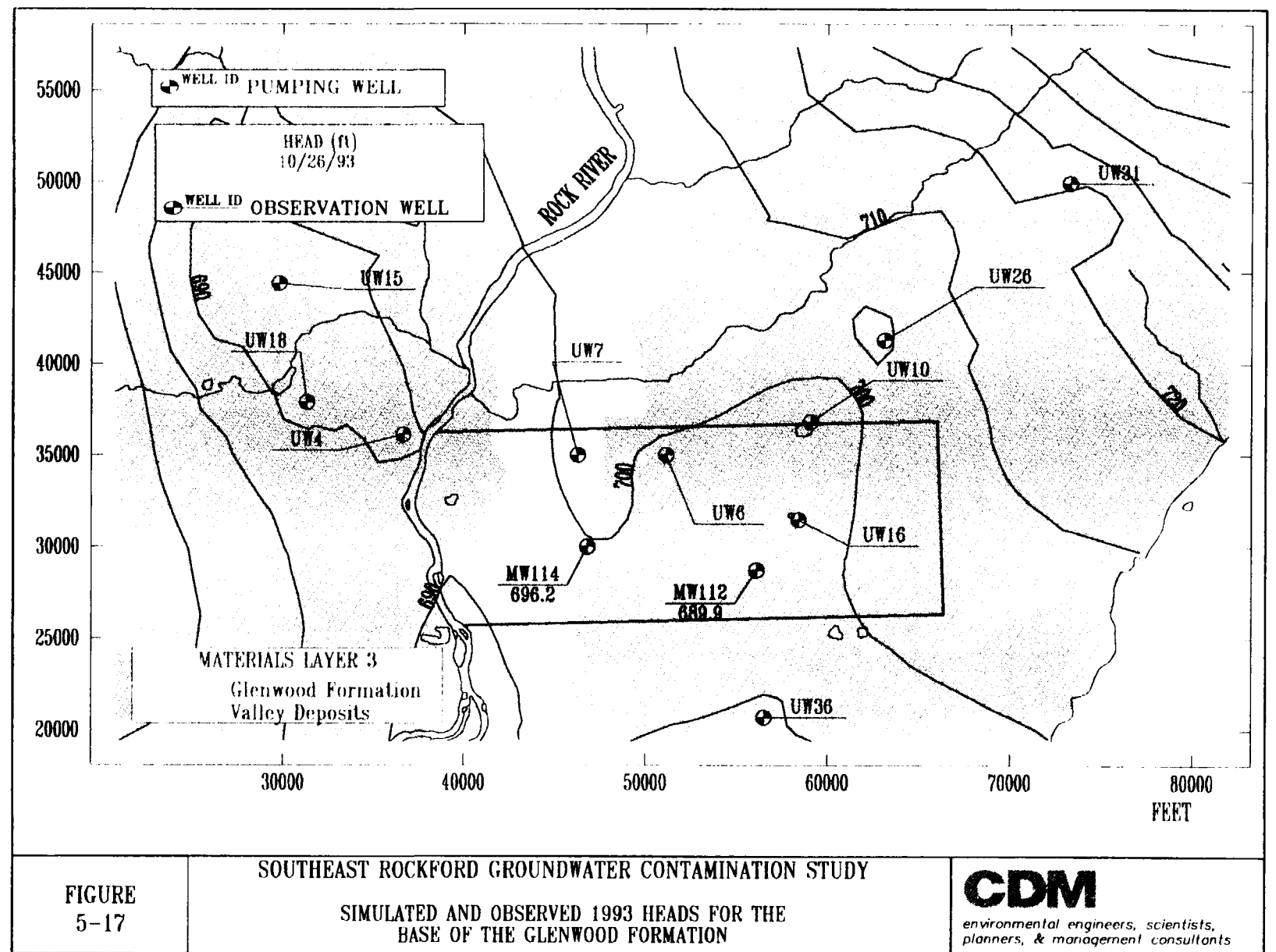
Simulated 1993 heads for the unconsolidated aquifer are shown in Figure 5-15. A prominent groundwater divide is visible between Alpine Road and Mulford Road, with relatively steep hydraulic gradients adjacent to the divide that flatten to both the east and west. This divide corresponds to the upland area separating the Kishwaukee and Rock Rivers. The groundwater divide is largely influenced by surface topography, and the decrease in hydraulic gradient near the Rock River is related to the relatively larger hydraulic conductivity and greater thickness of the Valley Deposits and Transition Deposits. The noticeable change in direction of groundwater flow to the southwest within the study area is a result of the orientation of the Rock River. The spatial distribution of simulated heads indicates that the unconsolidated aquifer discharges to the Rock River. A cross-sectional view of simulated 1993 heads is shown in Figure 5-16.

Figure 5-17 shows simulated 1993 heads for the base of the Glenwood Formation and the top of the St. Peter Sandstone. Several points may be made regarding the discharge of groundwater to the unconsolidated aquifer and the Rock River from the units underlying the Glenwood. Although regional flow is from east to west, there is a local divide in these units coincident with the eastern edge of the Valley Deposits. The causes of this divide are pumping at Unit Wells in the deep bedrock aquifers (St. Peter Sandstone and below), and the greater resistance to vertical flow from above provided by the Glenwood Formation relative to that in the Valley Deposits. In general, where the Glenwood has been eroded, the heads at this level exceed the heads specified from surface river nodes. This indicates that the underlying St. Peter Sandstone is discharging to the Rock River in these areas.

In the vicinity of pumping well UW4, vertically downward hydraulic gradients exist between the Rock River and the top of the St. Peter Sandstone; however, the confining properties of the overlying Glenwood would most likely limit direct flow from the river. The observed head difference of approximately 100 feet across the Glenwood at MW112, which is reproduced in the model, indicates that it is a confining layer. Based on the simulation, however, it is likely that Unit Well UW4 captures flow from the Valley Deposits by pulling groundwater beneath the Glenwood Formation, as shown in cross-section in Figure 5-18. The simulated 1993 head contours shown in Figure 5-18 indicate that Unit Wells UW4 and UW6 are capable of capturing flow from the Valley Deposits.







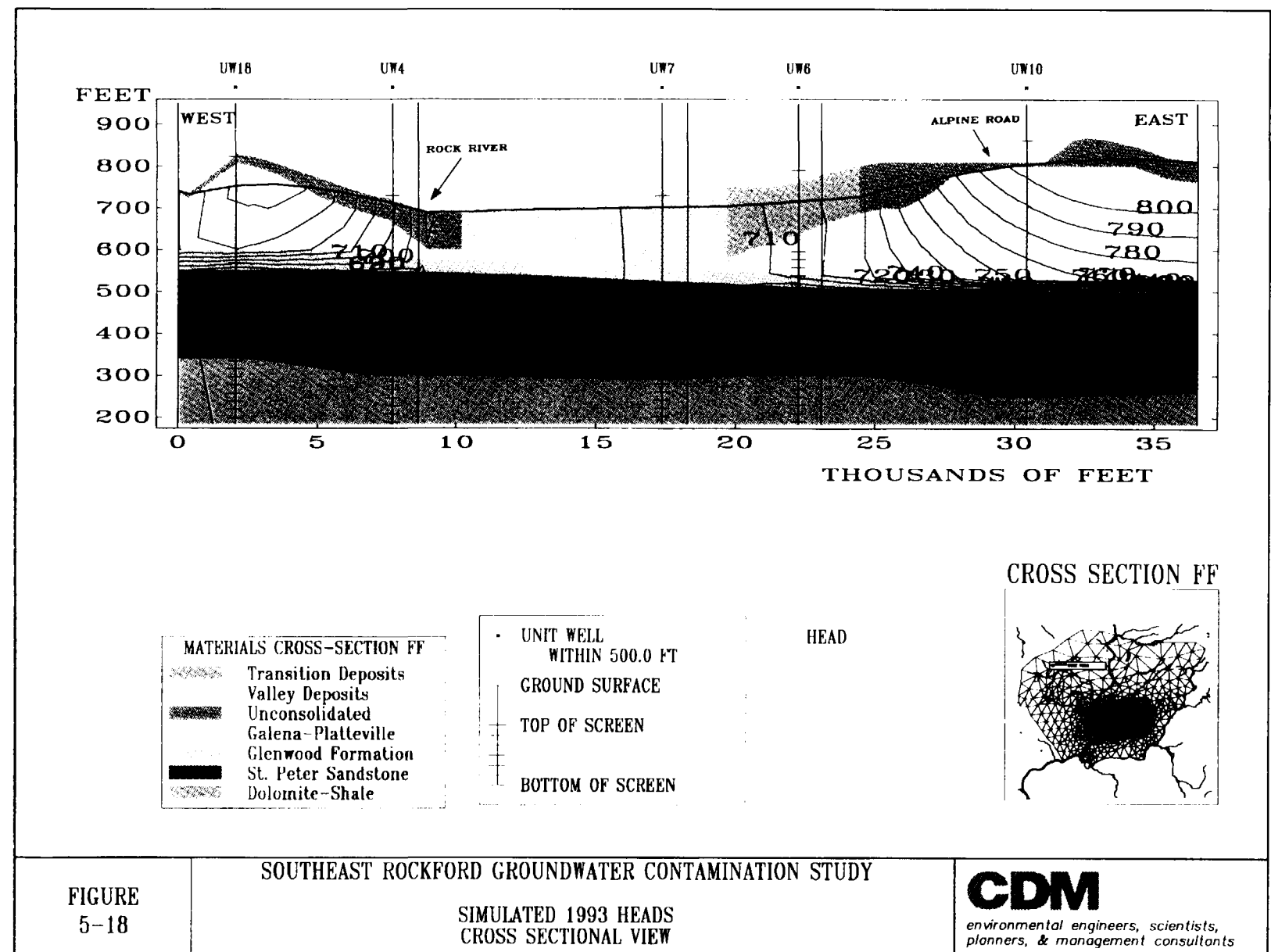


Table 5-3 contains calibration statistics by unit, including each well's measured head, simulated head, and the difference between the measured and simulated head. Comparison of simulated and measured heads is also shown graphically in Figure 5-15. Note that monitoring well MW102A was omitted from the calibration because of an anomalous water condition at that well. There is generally reasonable agreement between simulated and measured heads, with simulated heads on average approximately one-half foot lower than measured heads. It should be noted that the difference between simulated and measured values is largely due to unsimulated heterogeneity, and that the magnitude of these differences is generally greater in areas of high hydraulic gradients. The direction of vertical hydraulic gradients are well reproduced in the 1993 simulation; somewhat greater variability exists between the magnitude of the simulated and observed vertical hydraulic gradients. In general, however, the simulated horizontal and vertical hydraulic gradients agree reasonably well with the observed gradients.

5.5.2 Flow Mass Balance

Flow rates in a groundwater model are an important component of the overall modeled system, and an understanding of these fluxes is important for defining the characteristics and behavior of the system. Flow rates are determined during the calibration process. The resultant net flow values in the model are presented in Table 5-4. The water balance error (net flux divided by inflow or outflow) for the calibrated model is 0.5%. Ideally, the flow values in Table 5-4 are compared to measured fluxes during model calibration. However, for the Southeast Rockford model, known flux values were only available for pumping at the unit wells, which were specified as inputs. Measured values for the other flux components were not available.

5.5.3 Flow Sensitivity Analysis

Parameter sensitivity analysis was done to assess uncertainty in the groundwater flow model. Sensitivity analysis evaluates the response of the model to variations in parameter values. Determination of model response provides better understanding and confidence in the ability of the model to reasonably reproduce observed conditions. Details of the sensitivity analysis are given in Appendix M.

To evaluate the effect of recharge on modeled heads, flow simulations changing recharge by plus or minus 15 percent were done. Results of these simulations indicate that decreasing recharge by 15 percent increased the mean difference between observed and calculated heads from -0.5 feet to -3.3 feet, a decrease of 2.8 feet relative to the calibrated model. That is, the calculated heads were on average 3.3 feet lower than the observed heads when recharge was decreased. Conversely, calculated heads were on average 1.6 feet higher than observed heads when recharge was increased by 15 percent. This difference represents an average increase of 2.1 feet relative to the calibrated model.

5.6 Historical Flow Field

Historical flow fields encompassing the likely period (1955-1993) of contamination from source areas were required for simulation of past contaminant transport that created the current contaminant distribution. To develop the historical flow fields, potentiometric surface maps of

Table 5-3
Summary of Steady State Calibration by Well

WELL	Simulated Head (ft)	Measured Head on 10/26/93 (ft)	Difference (ft)
Wells Screened in St. Peter Sandstone (Layer 2)			
MW112C	696.98	689.88	7.10
MW114B	698.84	696.19	2.65
Mean for St. Peter			4.88
Standard Deviation St. Peter			3.14
No. of Wells St. Peter			2
Wells Screened in Galena-Platteville Group (Layer 4)			
MW101D	727.58	721.12	6.46
MW102C	750.99	749.90	1.09
MW103D	757.09	756.15	0.94
MW104C	777.40	780.30	-2.90
MW105D	774.95	782.89	-7.94
MW106C	781.74	788.24	-6.50
MW107C	795.53	796.64	-1.11
MW108C	802.16	800.47	1.69
MW113B	713.86	711.20	2.66
MW133C	755.23	760.81	-5.58
MW136	807.88	803.40	4.48
MW101B	729.68	725.24	4.44
MW101C	728.95	725.21	3.74
MW103B	770.42	776.56	-6.14
MW103C	766.91	776.69	-9.78
MW104B	780.12	781.29	-1.17
MW106B	786.27	787.12	-0.85
MW109B	817.62	825.28	-7.66
MW109C	813.14	825.12	-11.98
MW110C	810.57	819.78	-9.21
MW112B	789.79	796.59	-6.80
MW113A	714.49	712.10	2.39
Mean Galena-Platteville			-2.26
Standard Deviation Galena-Platteville			5.41
No. of Wells Galena-Platteville			22

Table 5-3
Summary of Steady State Calibration by Well

WELL	Simulated Head (ft)	Measured Head on 10/26/93 (ft)	Difference (ft)
Wells Screened in Unconsolidated Sediments (Layers 3,4,5)			
MW115B	729.24	727.82	1.42
MW118	695.92	695.78	0.13
MW122B	791.25	794.68	-3.43
MW134C	783.66	785.49	-1.83
MW135	792.83	799.31	-6.48
MW141	715.99	716.75	-0.76
IW1	703.53	700.72	2.81
IW3	703.53	700.76	2.77
IW4	703.91	701.04	2.87
IW5	703.88	700.91	2.97
MW101A	730.59	725.59	5.00
MW102B	753.71	751.80	1.91
MW103A	771.82	776.20	-4.38
MW104A	784.05	782.39	1.66
MW105A	782.42	782.08	0.34
MW105B	781.56	784.03	-2.47
MW105C	780.45	783.14	-2.69
MW106A	788.73	789.85	-1.12
MW107A	801.30	796.76	4.54
MW107B	800.69	796.84	3.85
MW108A	806.61	799.58	7.03
MW108B	805.96	799.82	6.14
MW109A	820.86	825.73	-4.87
MW109D	820.84	825.27	-4.43
MW110A	817.09	823.83	-6.74
MW110B	816.84	820.31	-3.47
MW111A	817.96	813.16	4.80
MW111B	817.74	812.95	4.79
MW112A	791.46	794.18	-2.72
MW114A	700.44	701.14	-0.70
MW115A	729.74	727.94	1.80
MW116A	696.61	696.74	-0.13
MW117A	689.63	690.64	-1.01
MW117B	689.77	690.63	-0.86

Table 5-3
Summary of Steady State Calibration by Well

WELL	Simulated Head (ft)	Measured Head on 10/26/93 (ft)	Difference (ft)
MW119	692.98	693.43	-0.45
MW121	693.76	694.60	-0.84
MW122A	792.86	794.83	-1.97
MW123	696.32	696.27	0.05
MW124	696.42	696.11	0.31
MW125	697.78	697.26	0.52
MW126A	697.54	697.02	0.52
MW126B	697.50	697.02	0.48
MW127	699.05	698.42	0.63
MW128	700.64	699.37	1.27
MW129	701.92	700.59	1.33
MW12	694.18	695.49	-1.31
MW130	704.35	704.56	-0.21
MW132	701.76	700.11	1.65
MW133A	757.26	755.49	1.77
MW133B	757.02	756.62	0.40
MW134A	784.40	788.49	-4.09
MW134B	784.03	787.79	-3.76
MW138	702.48	700.54	1.94
MW140	707.30	706.90	0.39
MW142	720.04	718.32	1.72
MW15	712.68	711.20	1.48
MW16	700.64	703.19	-2.55
MW17	702.59	703.06	-0.47
MW19	704.51	704.57	-0.06
MW20	698.33	698.23	0.10
MW21	698.98	702.92	-3.94
MW22	704.94	705.42	-0.48
MW24	700.45	705.21	-4.76
MW27	708.36	709.49	-1.13
MW29	696.19	699.55	-3.36
MW2	701.85	700.33	1.52
MW30	697.36	697.73	-0.37
MW31	700.58	703.24	-2.66
MW32	706.97	706.81	0.16
MW33	705.90	705.69	0.21

Table 5-3
Summary of Steady State Calibration by Well

WELL	Simulated Head (ft)	Measured Head on 10/26/93 (ft)	Difference (ft)
MW36	702.61	705.31	-2.70
MW38	700.73	701.52	-0.79
MW42	698.33	698.97	-0.64
MW43	696.14	696.85	-0.71
MW46	695.86	696.48	-0.62
MW47	693.25	694.53	-1.28
MW5	701.77	702.40	-0.63
MW1	701.81	700.37	1.44
MW9	696.12	700.55	-4.43
MW117C	690.00	691.21	-1.21
MW116B	696.55	696.72	-0.18
MW26	718.58	712.29	6.29
Mean Unconsolidated			-0.18
Standard Deviation Unconsolidated			2.80
No. of Wells Unconsolidated			82
Mean for All Wells			-0.53
Standard Deviation for All Wells			3.65
Total No. of Wells			106

TABLE 5-4
Net Fluxes in Calibrated Model

Component	Quantity (mgd)
Recharge	80.4
Pumping Withdrawals	-19.1
Subsurface Flow across Model Boundaries	- 1.5
Discharge to Rock River	-19.5
Discharge to Streams, etc.	-39.9
NET FLUX	0.4

Note: Positive values represent flow into the model
Negative values represent flow out of the model

the bedrock aquifers for 1971, 1975, 1980, 1985, and 1991 were obtained from regional groundwater studies (Sasman et al., 1982; Visocky, 1993). The maps were digitized and their values interpolated to the finite element grid to establish values for nodes with a specified head boundary condition.

In each case, a steady state simulation was performed to generate average conditions which would then be used for the transient transport simulations. The 1960 and 1965 flow models were generated by imposing the reported fluxes for each year and the 1971 boundary heads and performing a steady state flow field simulation. For the period 1971 to 1988, fluxes were modified annually and the boundary heads for the nearest available year were used. Flow fields were generated for each year over the period 1971 to 1988 in order to capture the year-to-year fluctuations in fluxes from wells in the vicinity of the study area. The calibrated steady state flow model described above was considered representative for the year 1993.

Figure 5-19 illustrates a typical historical head distribution for the top of the St. Peter Sandstone. No significant change in the direction of flow was observed in the bedrock aquifers. The most pertinent difference in the simulated flow fields was related to pumping at the unconsolidated wells closest to the study area including Unit Wells UW7A, UW38, UW14, and UW35.

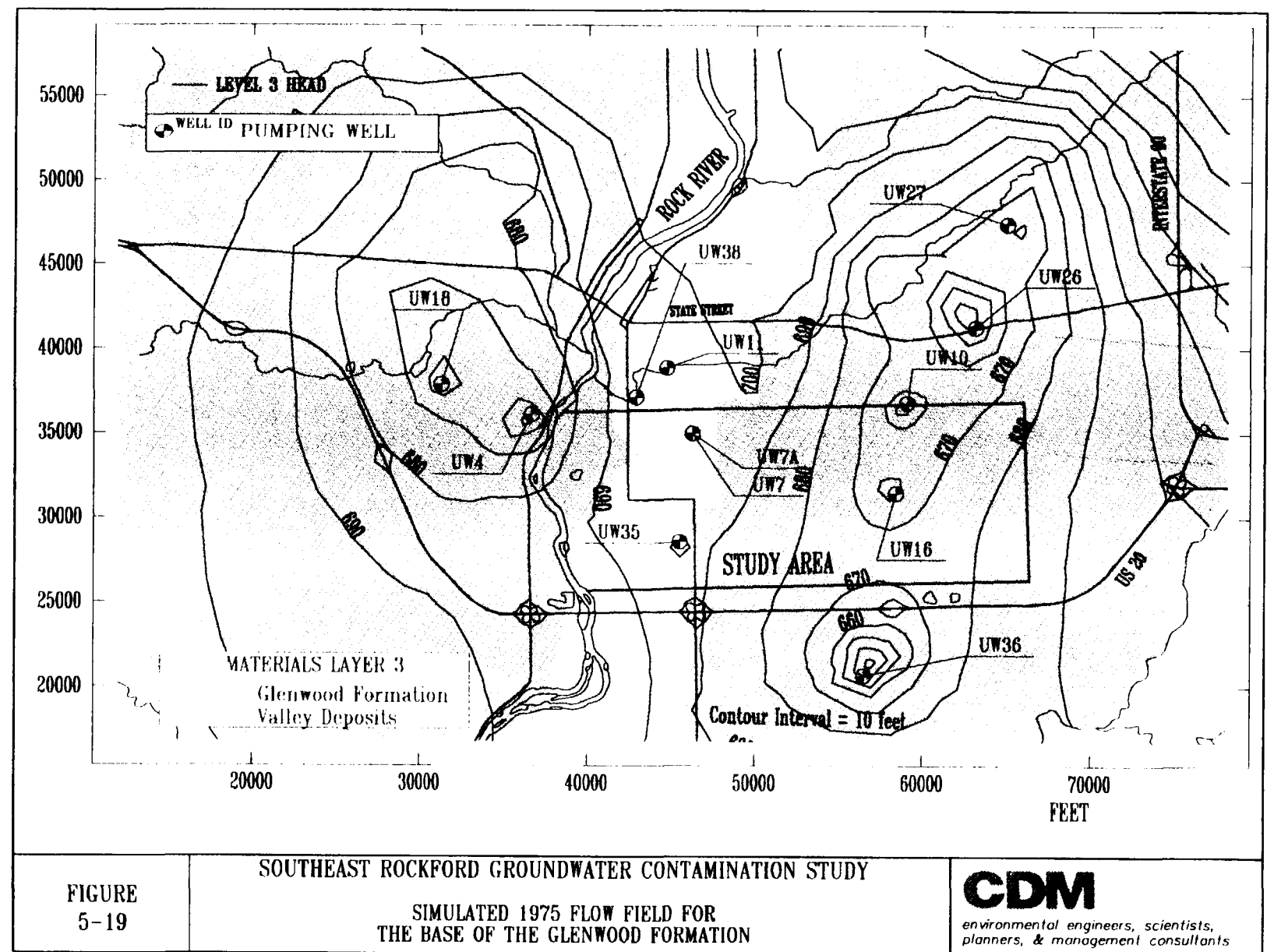
5.7 Contaminant Transport Simulations

This section describes the contaminant transport simulations performed as part of the Phase II Remedial Investigation. First the distribution of contaminants is described as it relates to the identification of sources and the principal contaminants of concern. Then, the primary transport processes governing the movement of contaminants are discussed, followed by a presentation of the contaminant transport code used in this project. Finally, the calibration process is discussed, along with the simulated transport parameters and source loading histories.

The objective of contaminant transport modeling in this phase were:

- evaluate the consistency of calibrated flow fields with the observed distribution of contaminants
- test hypotheses regarding contaminant source loading histories
- develop confidence in the model's ability to reasonably reproduce system behavior in anticipation of its use in evaluating remedial alternatives

Contaminant transport simulations of TCA and DCA were conducted of the Southeast Rockford Remedial Investigation study area for the period 1955 to the present. The models were implemented using the historical flow fields whose development was discussed in Section 5.6. Analyses of soil gas, water and soil samples were used to identify source areas and land use photos and other information sources were used where available to bracket the time history of disposal activities within the study area.

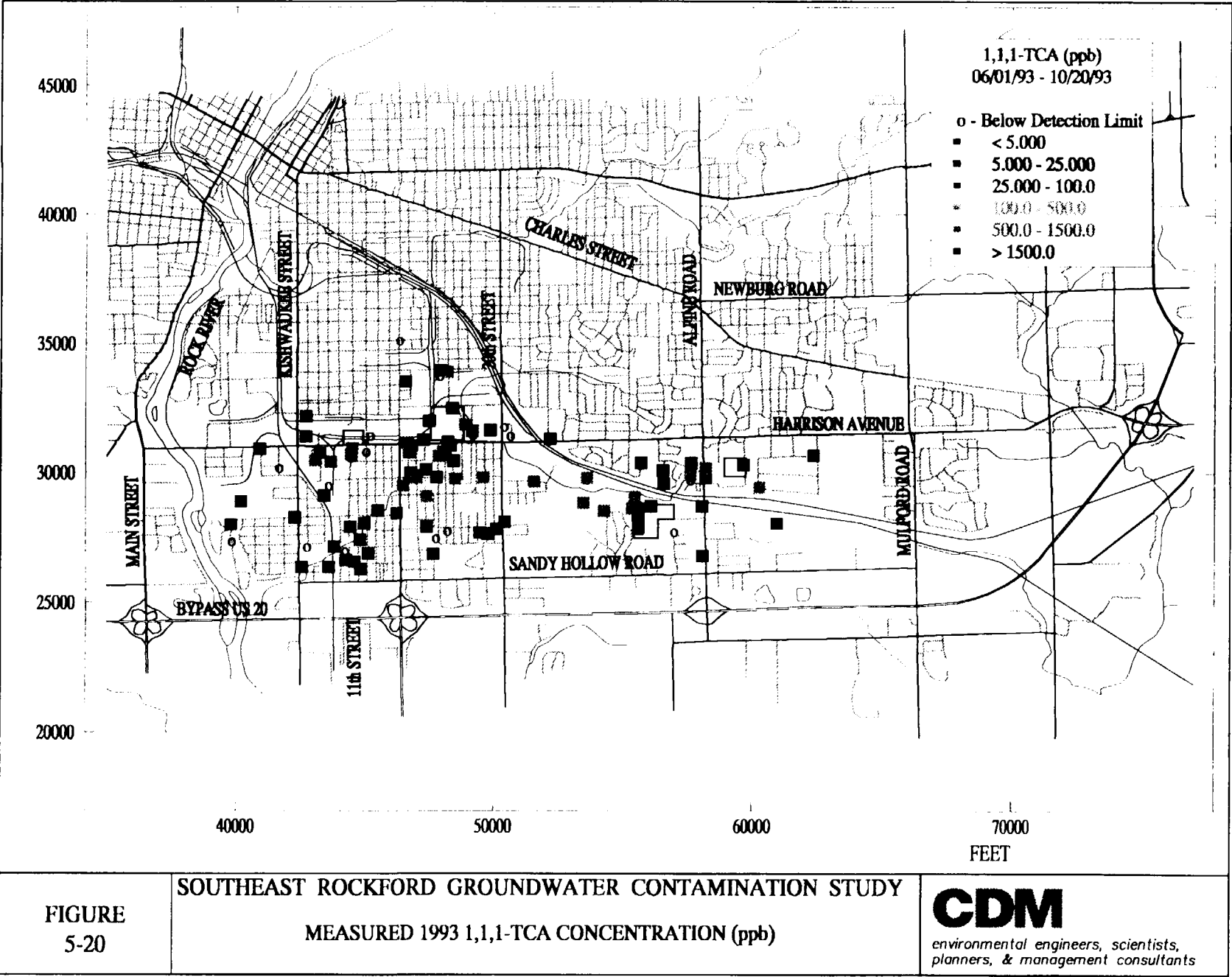


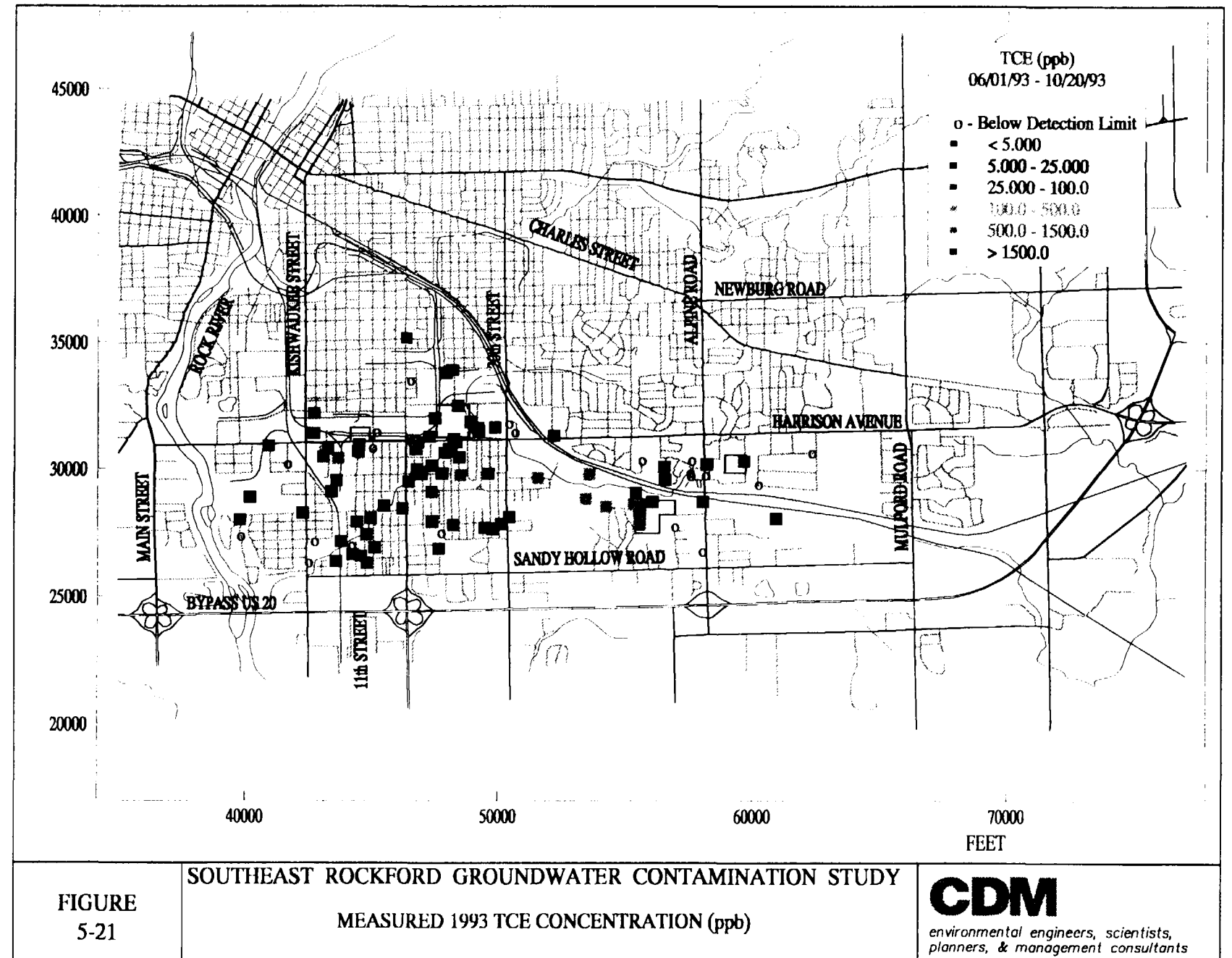
In the course of developing the transport simulations, refinements of the flow field model were implemented and applied in subsequent transport simulations. The transport model was found to reasonably represent the horizontal and vertical distribution of contaminants in the study area with transport parameters appropriate for each of the identified strata.

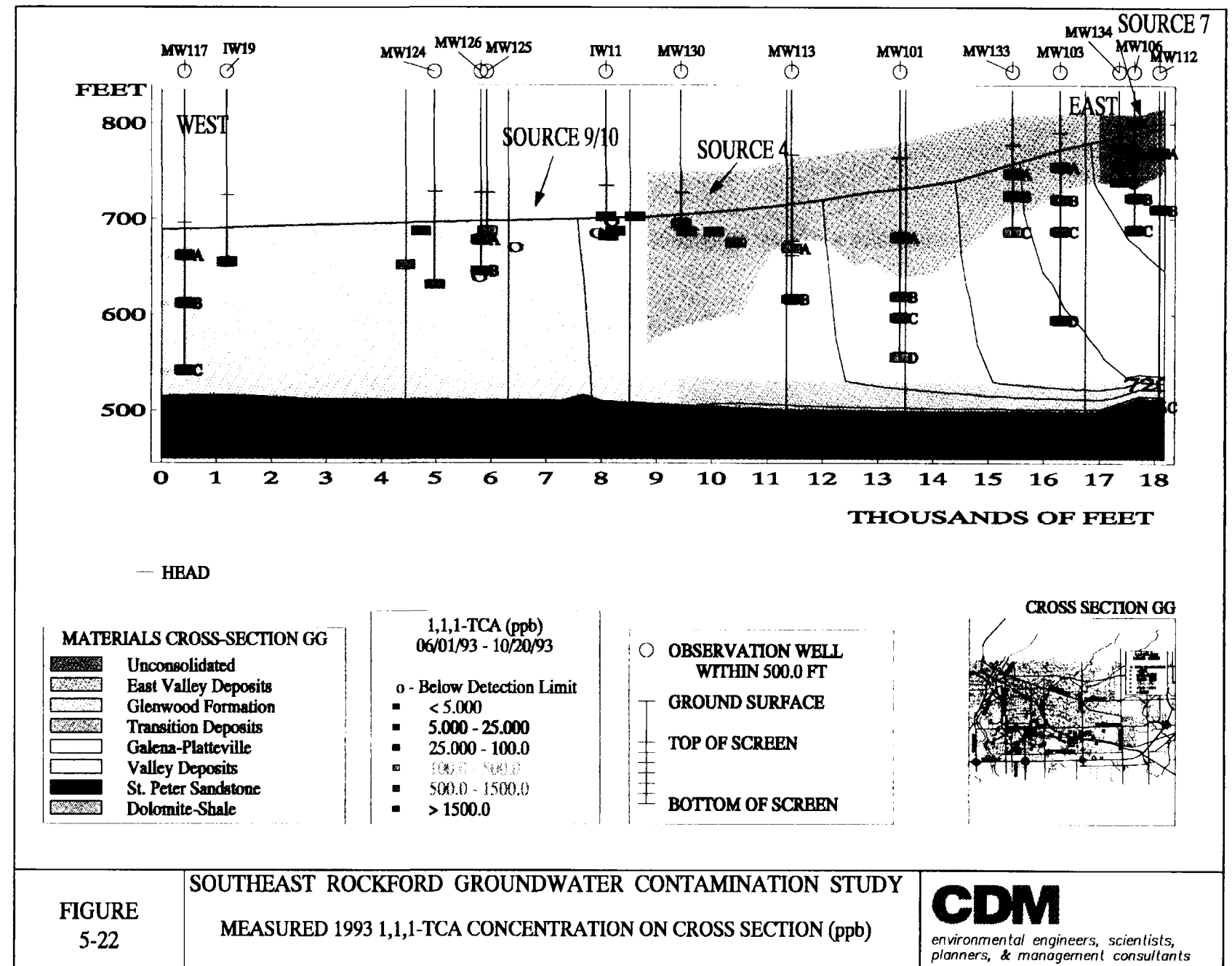
5.8 Distribution of Contaminants

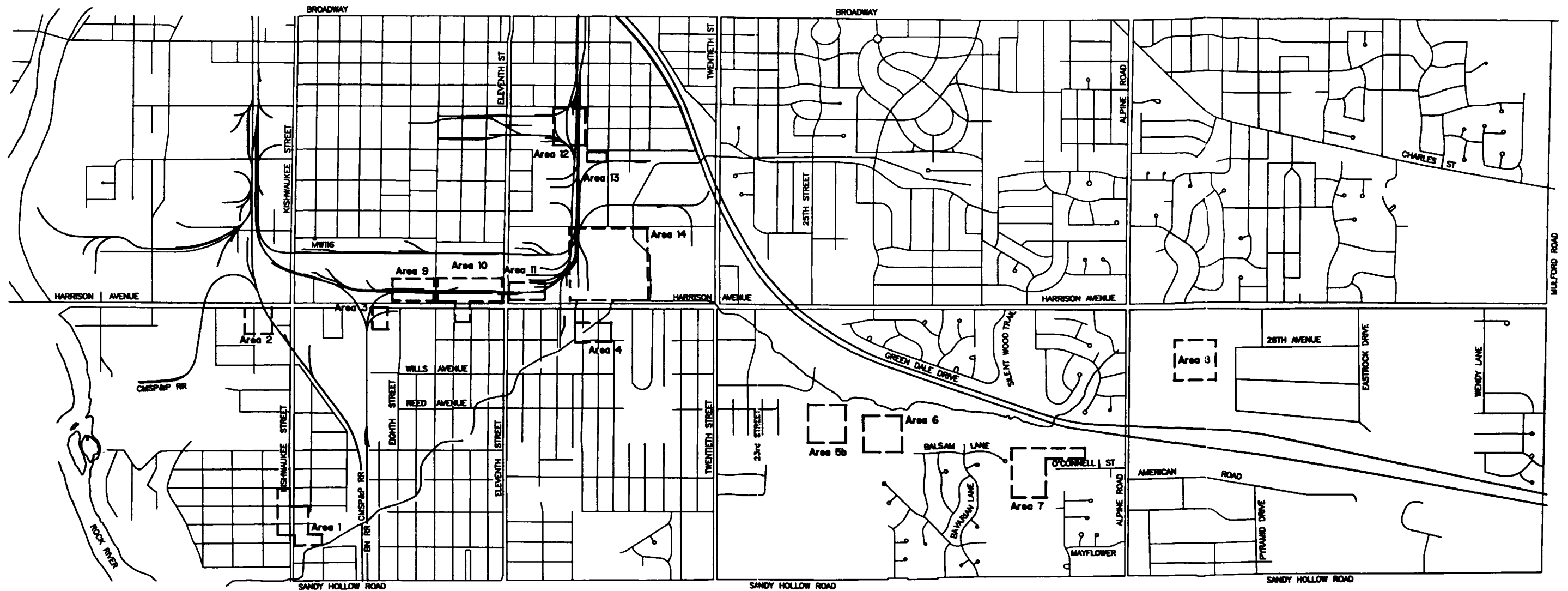
Section 4 of this report describes the distribution of contaminants based on field work performed in Phases I and II. That work included soil gas surveys and the collection and analysis of soil and water samples. The principal points described in that section are summarized in the following discussion.

- The principal contaminants of concern detected in the study area are VOCs including chlorinated hydrocarbons, BTEX compounds, and ketones. Compounds from both the PCE, TCE, DCE degradation chain and the TCA, DCA chain were frequently detected, however TCA was detected most frequently and generally at higher concentrations than the other VOC compounds. Figures 5-20 and 5-21 present the concentration of TCA and TCE measured in groundwater samples taken in the Phase II sampling round. At sampling locations with multiple wells, the plotted symbol is that corresponding to the highest measured value. Dissolved contaminant plumes are present in both the Unconsolidated and Galena-Platteville units. The low permeability Glenwood Formation limits the downward movement of contaminants below the Galena-Platteville. Figure 5-22 shows the TCA concentration at the elevation of the screen from which the groundwater samples were taken, superimposed over a east-west cross section showing site stratigraphy. Elevated concentrations of TCA are observed at and downgradient of the three sources intercepted by this cross section. Near the Rock River, the Galena-Platteville has been eroded and contaminants have been detected at low concentrations in the lower portions of the Valley Deposits.
- Fourteen potential source areas were identified in the Phase I study and in the early portions of the Phase II work (Figure 5-23). Water samples from Source Area 12 contained high concentrations of chlorinated VOCs; however since it is north of the Superfund site boundary (Harrison Avenue) and not upgradient of any portion of the Superfund site, it was omitted from the final list of potential source areas. The number of potential significant source areas has been reduced to five, (Areas 4, 7, 8, 9/10 and 14) based on the extent and magnitude of contamination found at each potential source area. More details on source evaluation are presented in Section 4 of this report.
- There are several wells in various parts of the study area with chlorinated VOC concentrations in the tens of ppb for which no source has been identified.
- The Area 8 plume contains elevated concentrations of TCA with significantly lower concentrations of PCE and TCE. The plume extends a distance of approximately 3,000 feet west of the source area and is largely confined to the uppermost 75 feet of the saturated zone. BTEX compounds are present as well with a peak measured concentration of 2,200 ppb.







**LEGEND:**

GENERALIZED SOURCE AREA



SCALE:

500 0 1000 Feet

SOUTHEAST ROCKFORD
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**LOCATION MAP OF POTENTIAL SOURCE AREAS
SHOWING GENERALIZED BOUNDARIES**

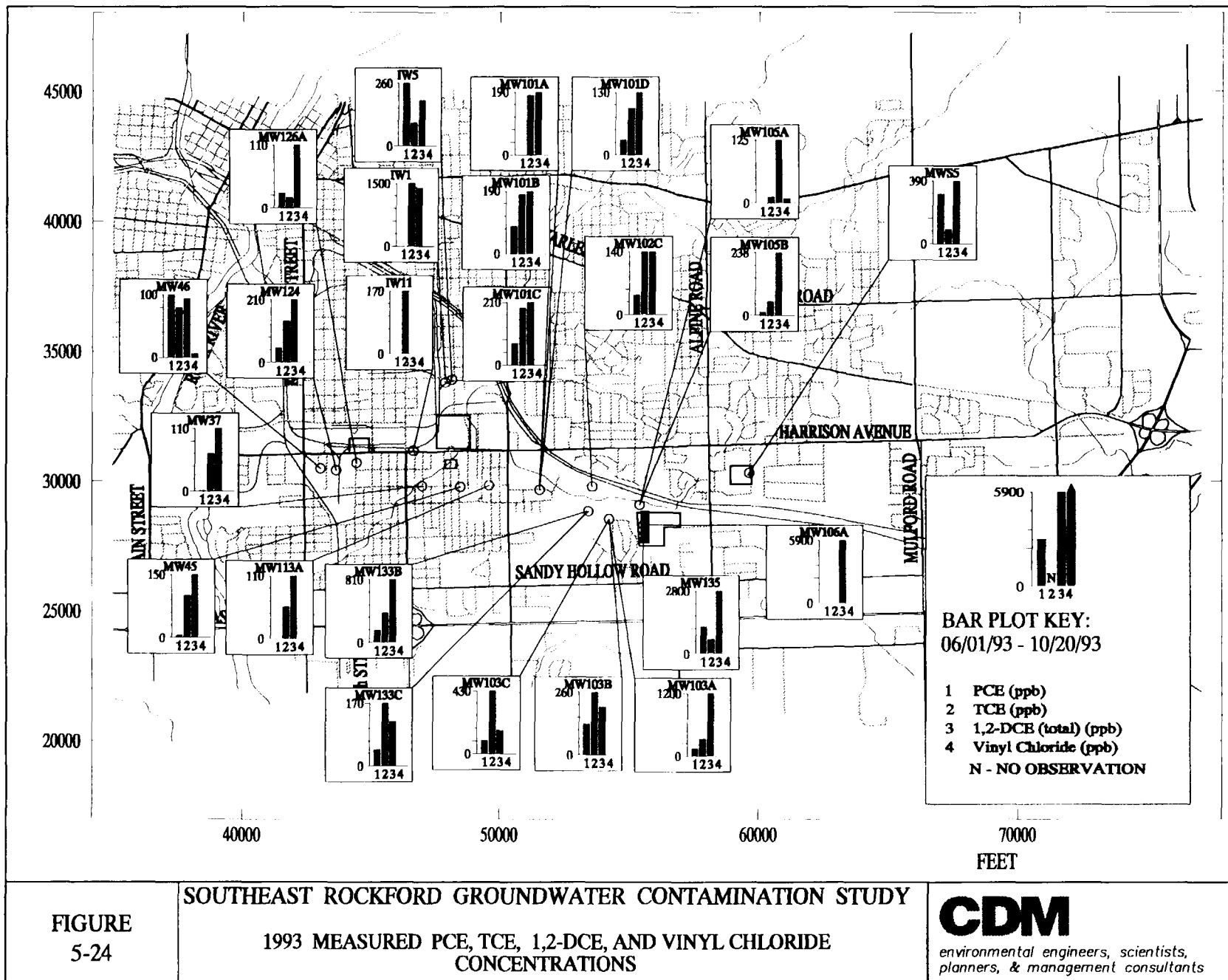
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- The Area 7 plume is the largest single plume both in terms of length (approximately 2 miles) and mass of contaminants contained in the plume. An aerial photograph of the study area taken in 1958 show evidence of disposal activities. The highest measured TCA values in the Phase II sampling round, 8,000 ppb and 7,900 ppb, are found at monitoring wells MW135 and MW106A immediately downgradient of this source area. The plume penetrates the Galena-Platteville unit, eventually reaching a depth below the water table of at least 175 feet. TCE and PCE are also present at elevated concentrations in the Area 7 plume.
- The Area 4 plume has a high TCA content with low concentrations of TCE and no detectable PCE. The plume is intercepted by monitoring well MW130, which has a measured TCA concentration of 1,000 ppb. The concentrations of TCE and DCA at that well are 28 and 26 ppb respectively. Soil samples taken at the suspected source area revealed the presence of an eight foot thickness of a dark, oily product at the top of the saturated zone.
- The source of contaminants to the Area 14 plume is a "chip pit" used for temporary disposal of metal trimmings. The chip pit and surrounding soil was apparently removed in 1988; surrounding soils were sampled at that time and were found to contain ppm-level concentrations of numerous chlorinated VOCs. Chip pit soil contained high concentrations (ppm-level) of VOCs. A black, oily product was detected in Phase II soil borings of five to seven feet containing elevated levels of PAH compounds. The PAH compounds were not present at depth and relatively low levels of VOCs were detected in deeper samples. It is considered unlikely that Area 14 is an ongoing source of contamination, but the previous presence of the chip pit and associated contaminated soils make it possible that this was a significant source prior to its remediation.
- The Area 9/10 plume contains elevated concentrations of TCA and its daughter products. Chloroethane, which is a degradation product of DCA, was observed in seven wells downgradient of source Area 9/10. The advanced state of degradation of VOCs in the Area 9/10 plume, both TCE and TCA, is attributed to the presence of an upgradient BTEX plume which partially merges with the Area 9/10 plume. Figure 5-24 shows the concentration of PCE, TCE and DCE for wells with at least one compound exceeding 100 ppb. Likewise, Figure 5-25 shows the concentration of TCA and DCA at wells with at least one compound exceeding 100 ppb. Take note in particular of monitoring wells MW124 and MW126A in Figure 5-24, and MW126A and MW125 in Figure 5-25, which are all in the Source Area 9/10 plume and contain high concentrations of daughter products. The aerobically degradable BTEX contaminants have exhausted the oxygen supply in the region of the Area 9/10 plume, creating ideal conditions for the anaerobic, biological degradation of TCA/TCE and its related daughter products.

5.9 Transport Processes

This section describes the primary processes affecting the transport of contaminants in porous media.



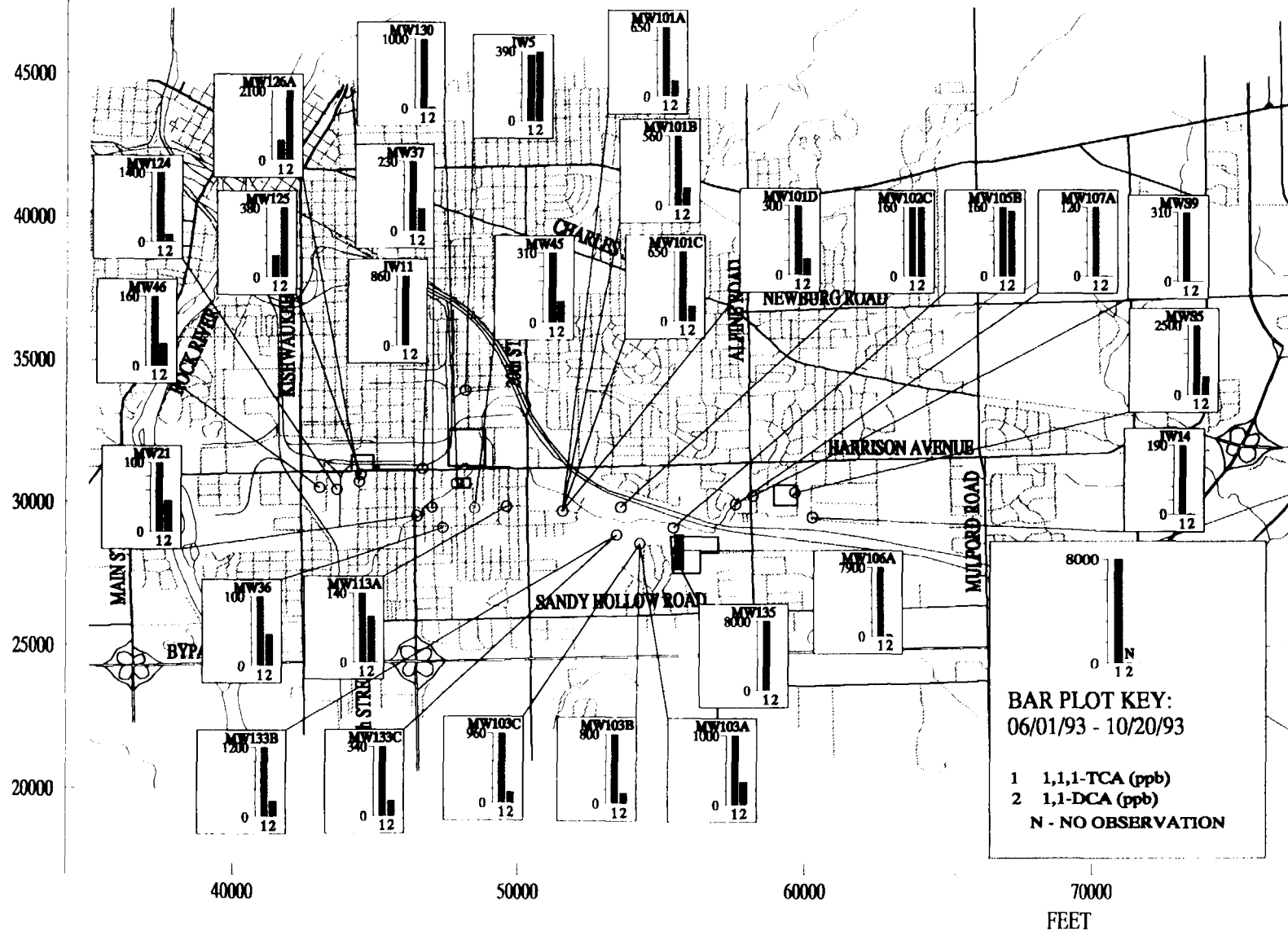


FIGURE
5-25

SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY
 1993 MEASURED TCA AND 1,1-DCA CONCENTRATIONS

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Flow through Unsaturated Zone. Contamination released to the unsaturated soil zone will infiltrate downward, with a portion retained in the soil by capillary tension as it infiltrates. If the volume of the release is great enough part of the contaminant will reach the water table rapidly by direct infiltration. Contamination retained in the unsaturated zone soil pores will be slowly leached by infiltrating recharge water and carried to the water table, typically at an exponentially decaying rate.

Advection of Dissolved Phase. In the saturated zone, contaminants dissolved in groundwater move at an average velocity proportional to the specific discharge of flowing groundwater. If the contaminant does not adsorb to the solid phase, the average contaminant velocity will be the same as the velocity of groundwater.

For a given gradient and hydraulic conductivity, the velocity of groundwater flow and therefore the rate of contaminant advection is inversely proportional to the aquifer's effective porosity. Effective porosity is the proportion of the bulk soil volume through which groundwater flows. It may differ from the measured porosity since some pore space may occur as dead ends that are not interconnected and therefore do not contribute to the pore volume through which water may pass. Also, when calculating the bulk porosity of a unit that is internally stratified, the observed porosity is the pore volume of the transmissive portion of the unit divided by the bulk volume of the entire unit.

Adsorption. The adsorbed mass concentration (adsorbed mass per unit mass of dry solids) may be expressed as a linear function of the concentration in solution:

$$C' = K_d C_s$$

where K_d is the distribution coefficient, C' is the adsorbed mass concentration, and C_s is the solution concentration. This relationship is appropriate for partitioning of compounds when the reactions that cause partitioning are reversible and occur rapidly relative to the velocity of the pore water. For dissolved contaminants that have any tendency to adsorb to the stationary soil phase, there is an apparent retardation of the average contaminant velocity relative to that of the groundwater. In modeling the movement of contaminants with flowing groundwater, the retardation factor, R_f , is defined and calculated as follows:

$$R_f = \frac{\text{Average Velocity of Water}}{\text{Average Velocity of Contaminant}}$$

which may be approximated as:

$$R_f = 1 + \frac{\rho_b}{n} K_d$$

where:

K_d = distribution coefficient
 ρ_b = bulk density of soil
 n = porosity

Degradation. The total mass which enters an aquifer may be reduced by biological and chemical decay mechanisms. Biochemical degradation rates are typically represented as a first order differential equation, whose solution may be expressed as a function of time as follows:

$$c_{t+\Delta t} = c_t e^{-k\Delta t}$$

where:

k = decay coefficient (1/time)
 c_t = concentration at time t
 Δt = time increment

Decay rates are also frequently expressed in terms of "half life", which is the time required to reduce the mass of a compound by 1/2. The half life as a function of the rate constant is as follows:

$$t_{1/2} = -\frac{\ln(1/2)}{k} = \frac{0.69}{k}$$

Decay rates are dependent on aquifer, groundwater and contaminant properties. While TCA is typically more persistent than many other common groundwater contaminants, e.g. petroleum hydrocarbons, TCA is known to degrade in groundwater to 1,1-DCA under anaerobic conditions or to 1,1-DCE in an abiotic reaction. 1,1-DCA will in turn degrade to chloroethane also under anaerobic conditions. 1,1-DCE degrades to vinyl chloride under anaerobic conditions. Ultimately, both the abiotic and biological degradation chains result in the degradation of the chlorinated hydrocarbons into CO_2 , water, and chloride.

Given that TCA and DCA decay at different rates, the changing ratio of the two compounds downgradient of a source area may be used as an indicator of the rate of contaminant decay of the two compounds. For a pure TCA source of concentration, c_{TCA} the equations governing its decay to DCA and CA are as follows:

$$\frac{dc_{\text{TCA}}}{dt} = -k_{\text{TCA}} c_{\text{TCA}}$$

$$\frac{dc_{DCA}}{dt} = -k_{DCA}c_{DCA} + k_{TCA}c_{TCA}$$

$$c_{TCA}(0) = c_{TCA0}, \quad c_{DCA}(0) = 0$$

This model of degradation neglects the loss of mass between products in the degradation chain, and assumes that sorption, solubility, and volatility is similar for each compound, and assumes a pure TCA source. The solution for this system may be expressed as follows:

$$c_{TCA}(t) = c_{TCA0}e^{-k_{TCA}t}$$

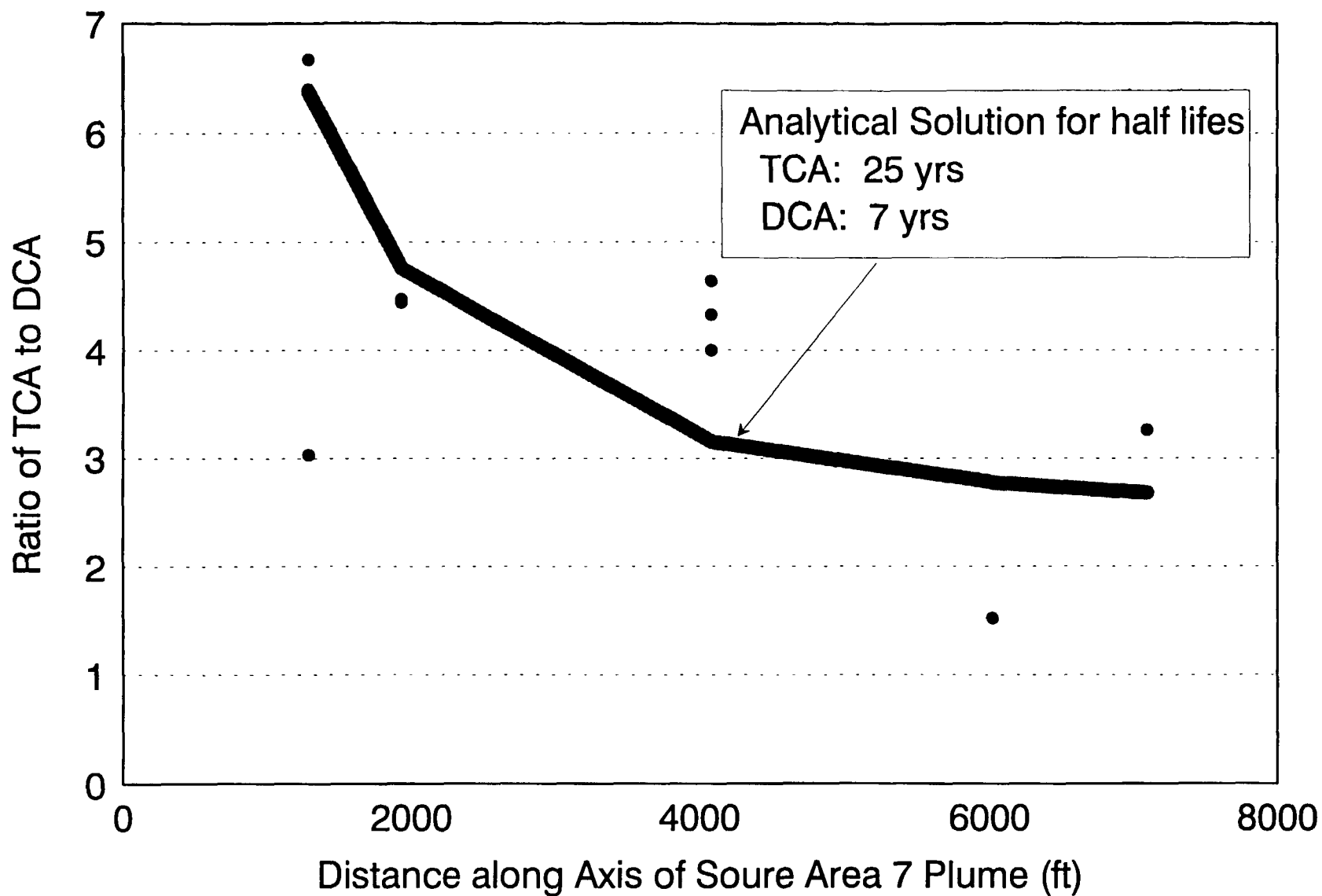
$$c_{DCA}(t) = \frac{k_{TCA}c_{TCA0}}{k_{DCA} - k_{TCA}} (e^{-k_{TCA}t} - e^{-k_{DCA}t})$$

The relative concentration of TCA and DCA over time can be used to estimate the contaminant degradation rates. Taking $k_{TCA} = k_{DCA}/3.5$, from the range of degradation rates cited in the handbook of Environmental Degradation Rates, then the ratio of TCA to DCA as a function of time may be reduced to the expression:

$$3.5k_{TCA} = k_{DCA} = \frac{1}{-0.7t} \ln \left(1 - \frac{2.5c_{DCA}}{c_{TCA}} \right)$$

Figure 5-26 shows the ratio of TCA:DCA as a function of distance from Source Area 7. Assuming that flow is constant over time and distance, then the distance from the source area can be related as a linear function of the travel time. Assuming a travel time of 35 years to reach a distance of 7,000 feet from Source Area 7, a half life of 25 years for TCA and 7 years for DCA was found to fit the trend in the measured data. It should be noted that there is a good deal of scatter implying that this analysis has not captured all of the factors affecting the rates of degradation. These factors may include variable oxygen content, differences in adsorption and solubility between the two compounds, the decay of TCA at the source, and non-first order decay process.

The contaminant transport model, DYNTRACK, is a single species model which enables simulation of exponential decay, whereby the decayed mass is lost to the system. Since simulations are to be made of the combined mass of TCA and DCA, it is necessary to use an



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GROUNDWATER CONTAMINATION STUDY

RATIO OF TCA TO DCA
VERSUS DISTANCE FROM SOURCE AREA 7

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FIGURE 5-26

equivalent decay rate, such that the half life of this process is equivalent to the time necessary for a specified mass of TCA to degrade to a combined mass of TCA and DCA which is half the original mass. Given the decay rates, the following equation may be solved for t using simple numeric methods:

$$(1/2)c_{TCA}(0) = c_{TCA}(t) + c_{DCA}(t)$$

Using the decay rates estimated above, the half life of TCA+DCA as defined above is 36 years.

Dispersion. The macro-dispersion process represents temporal and spatial flow field variations which are not explicitly represented by advective transport of the plume's center of mass. Longitudinal dispersivity applies in the direction of flow, and transverse dispersivity applies perpendicular to the direction of flow. To represent the bedded nature of unconsolidated deposits, DYNTRACK applies a vertical anisotropy ratio to the dispersion to account for reduced vertical dispersion with respect to horizontal dispersion.

5.10 Contaminant Transport Code

CDM's contaminant transport code, DYNTRACK, was used to simulate the movement of dissolved contaminants in porous media. DYNTRACK uses a Lagrangian approach to approximate the solution of the convection-dispersion equation:

$$R \theta \frac{\partial C}{\partial t} = \frac{\partial}{\partial x_i} (D_{ij} \frac{\partial C}{\partial x_j}) - q_i C - \lambda C$$

where C is the concentration at any point, θ is the effective porosity, R is the retardation factor, q_i is the specific discharge, D_{ij} is the total area dispersion tensor (αq) where α is the dispersivity, and λ is the contaminant decay rate. The first term in the right hand side of the equation represents the dispersive flux as embodied by Fick's law; the second term represents the convective flux.

This process uses the random walk method for a statistically significant number of particles, wherein each particle is convected with the mean velocity within an element and then randomly dispersed according to the specified dispersion parameters. The first task of the transport code is to determine the mean velocity in each component direction within each element. This is computed from the element geometry, material properties, and nodal point potentiometric heads using Darcy's Law, which expresses flow rate as a function of the hydraulic gradient. The seepage velocity, which represents the mean rate of contamination movement, is then computed as Darcy's velocity divided by effective porosity. The contaminant velocity is the seepage velocity divided by the retardation factor.

Potentiometric heads used in the DYNTRACK model are first computed by DYNFLOW. From a computed set of potentiometric heads, the specific discharge vector in each finite element is computed by Darcy's Law.

$$q_i = K_{ij} \frac{\partial \Phi}{\partial x_j} \quad i,j=1,3$$

where q_i is the specific discharge, K_{ij} is the hydraulic conductivity tensor, and Φ is the potentiometric head. The velocity vector is unaffected by the contaminant concentration in the element, and thus, density gradients are not considered.

In the DYNTRACK code a contaminant source can be represented as an instantaneous input of contamination, as a continuous source in which particles are input at a constant rate of each time step, or as a specified concentration at a node. The concentration of contamination within a particular area or volume of interest is represented by the sum of the weight of particles that are present within the volume divided by the volume of interest times the porosity and the retardation factor. By assigning the mass associated with each particle and the rate at which particles are input to the system, a specified mass flux boundary can be directly simulated.

DYNTRACK has been documented by the International Ground Water Modeling Center of the Holcomb Research Institute (van der Heijde, 1985).

5.11 Calibration of Transport Model

Transport simulations of TCA-DCA were performed with contaminant sources at Source Areas 4, 7, 8, 9/10, and 14. TCA and DCA were simulated because they are present most consistently and at higher concentrations than other contaminants, and are generally good indicators of the presence of other VOCs. The earliest simulated release of contaminants was at Source Area 7 in 1955. Simulations were performed up to October 1993 for each source, for four sequential, historical periods of contamination. The sources were weighted and the composite contaminant distribution used to represent the simulation of existing contamination. The simulations used a sequence of historical flow fields generated by imposing recorded piezometric head values at specified boundary nodes and adjusting pumping rates to values reported by the Illinois State Water Survey and the Rockford Water Division, as previously described in this section.

Calibration of the contaminant transport model was carried out in three phases:

- particle track simulations to bracket limits of transport parameters and timing of releases
- refinement of estimates of dispersion and porosity by comparing general shape and depth of contaminant plumes with initial particle cloud simulations

- refinement of location and timing of contaminant sources by comparing measured and simulated concentrations

Transport parameter values were selected based on the field measurements, published literature and CDM's modeling experience at other sites. These values were later refined during calibration. Table 5-5 shows the simulated transport parameters as adopted in the second step of the calibration. No properties are reported for Layers 1, 2 and 3, representing the Dolomite-Shale, St. Peter Sandstone and Glenwood Formation, due to the lack of contamination in these units.

The porosity values in the Unconsolidated and East Valley units should be interpreted as representing a bulk porosity for the unit as a whole. Both of these units are highly stratified glacial deposits with lenses of low permeability silts and clays interbedded with more transmissive coarse sands. The simulated porosity reflects this interbedding and the presence of a significant bulk of the strata through which flow is minimal; it is thus an appropriate estimate of the bulk effective porosity of the unit as a whole.

Table 5-5
Transport Properties

Soil	Layers	Retardation	Porosity
Valley Deposits	3, 4, 5	1.5	.175
Galena-Platteville	4	1.2	.1
Unconsolidated	5	1.5	.11
East Valley Deposits	5	1.5	.11
Transition Deposits	4, 5	1.5	.175

Properties Shared by All Soil Types:

degradation rate - 36 yr half life
longitudinal dispersivity - 100 ft
transverse dispersivity - 10 ft

The simulated porosity in the Galena-Platteville dolomite is typical for a fractured rock aquifer. Its retardation factor is less than the overlying deposits, due to the absence of organic materials in units of this type. As a result, there is less adsorption of organic contaminants and less retardation of contaminant movement relative to the groundwater velocity.

Numerous transient simulations were run, varying both the location and timing of contaminant mass loadings and the rate of degradation. The final set of source loadings were determined based on the ability to replicate existing contamination at monitoring wells and consistency with what is known of land use and disposal practices at identified source areas within the study area. The simulated loading weights arrived at during calibration are summarized in Table 5-6. It should be noted that these loading weights are estimates only. The source locations and loading histories proposed in this section should not be construed to be precise representations. They are however, consistent with and supported by factual evidence and model simulations, and are believed to reasonably reflect overall trends both spatially and temporally.

In Figure 5-27 contours of simulated Level 5 TCA-DCA are drawn along with symbols showing the measured concentration of the two compounds. The footprint of the simulated plume conforms generally to the areas of measured concentrations in the groundwater, and the areas of highest concentration match the areas of greatest simulated concentration with the same approximate magnitude.

5.11.1 Source Area 8

Initially, Source Area 8 was simulated as a rectangular source centered on the portion of the site presumed to contribute most significantly to the contaminant plume. Transport simulations using the source defined in this manner were not able to replicate the distribution of contamination measured in the field. Contaminant particles introduced at this area were transported by the flow field with a downward vertical component too high to reproduce the shallow downgradient concentrations.

Subsequent simulations of Source Area 8 used two source areas, the first coincident with the site boundaries as before and the second as a source at the water table starting at Source 8 and extending 2,000 feet downgradient. The latter source represents the presence of a non-aqueous phase consisting of a mix of hydrocarbons and chlorinated hydrocarbon solvents. BTEX measurements of 2,200 ppb have been reported in water samples downgradient of the source area, although available information does not explicitly mention the presence of a non-aqueous phase. It should be noted that the postulated existence of NAPL-related plume is tentative, and subject to revision pending availability of further information. Additional data is required to verify the existence of a non-aqueous plume in this area.

In general, the horizontal movement of a non-aqueous phase plume is slower than that of a dissolved contaminant plume due to the resistance of capillary pressure at the plume's interface with the water saturated soils. The movement and arrival of the non-

Table 5-6

Estimated Source Loading Weights (kg/yr)

Source Area	1955-1969	1970-1975	1976-1985	1986-1993
4			200	100
7	600	450	300	250
8			100	60
8 (non-aqueous phase)				10
9/10		300	200	100
14			20	20 ¹

¹Source 14 source stops in 1988 when excavation of contaminated soil completed

aqueous phase were not simulated. The reported timing of this NAPL source represents the period during which the NAPL was present and available as a source to the dissolved contaminant plume. Area 8 simulations used 1967 as the start date because the facility associated with this source was built in that year.

Figure 5-28 shows the Source Area 8 plume superimposed over a cross section taken along the plume's longitudinal axis. The black rectangles in Figure 5-28 represent contaminant particles. Note that the highest measured, and simulated, concentrations in this plume are found in the immediate area of the source. The downgradient plume intersecting monitoring wells MW107A, MW107B, MW122A, and MWS9 is a result of the simulated non-aqueous phase source extending westward of Source Area 8.

5.11.2 Source Area 7

The simulated start date for Source Area 7 was 1955. The source has the highest loading values and the earliest start date due to the longitudinal extent of the plume and the intensity of the concentrations measured within the plume and at its source. As previously reported, an aerial photograph from 1958 showed evidence of disposal activities at this source area. The source is represented as being at its peak during the period 1955 - 1969, with declining loadings thereafter, where loading is defined as the additional mass contributed to the dissolved contaminant plume at the water table.

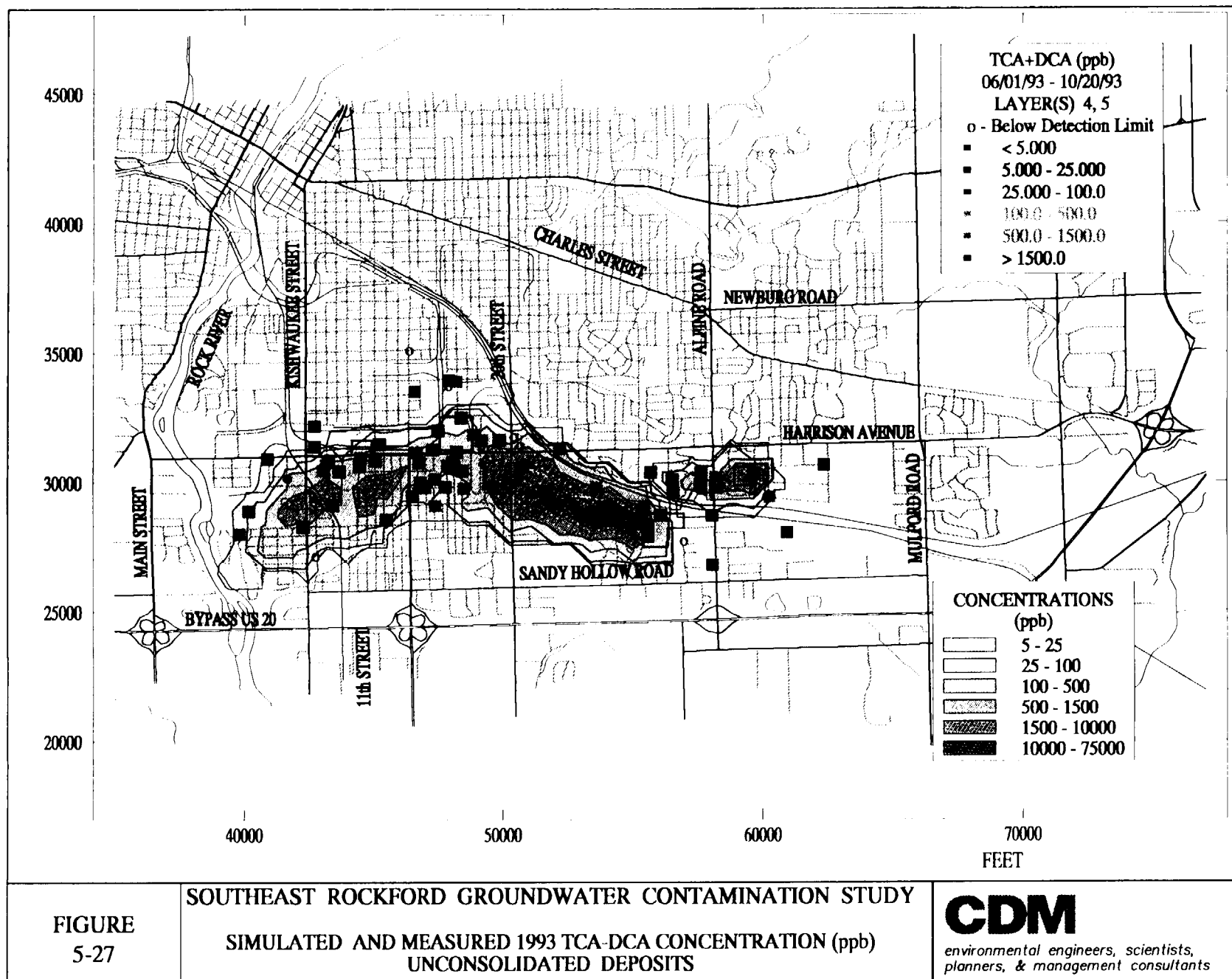


FIGURE
5-27

SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY
SIMULATED AND MEASURED 1993 TCA-DCA CONCENTRATION (ppb)
UNCONSOLIDATED DEPOSITS

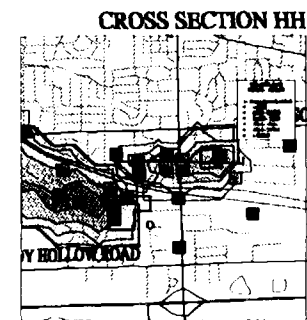
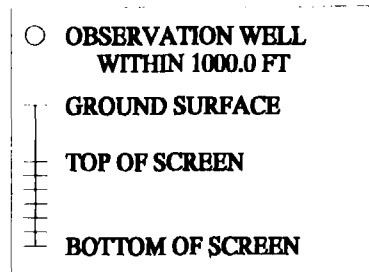
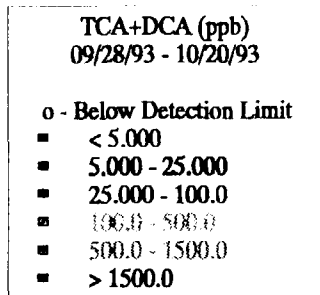
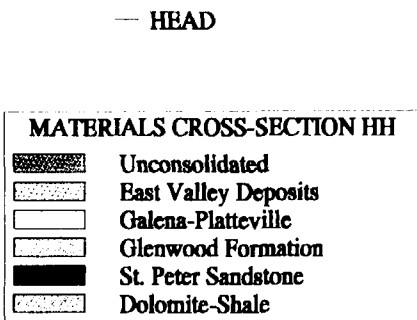
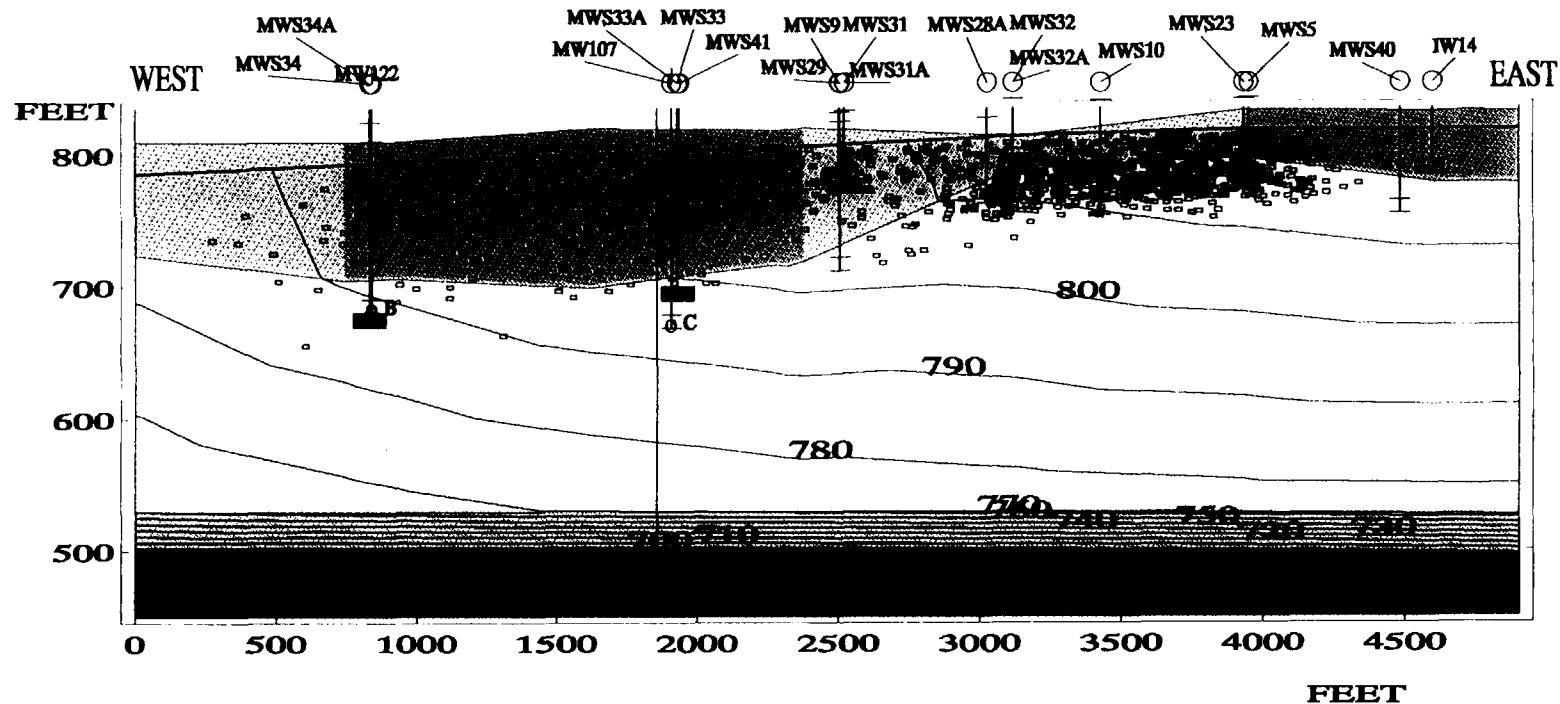


FIGURE
5-28

SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY
1993 MEASURED TCA-DCA CONCENTRATIONS (ppb) AND SIMULATED PLUME
ALONG AXIS OF SOURCE 8 PLUME

CDM

environmental engineers, scientists,
planners, & management consultants

The Area 7 plume maintains a concentration of 100 ppb as far as 8,000 feet from its source. Figure 5-29 presents a cross section along the axis of the plume, along with measured concentrations of the combined concentration of TCA and DCA from the Phase II field work. The black rectangles in Figure 5-29 represent contaminant particles. The general shape and depth of the simulated plume matches the measured values.

5.11.3 Source Area 4

The simulated Area 4 plume contaminant loading begins in 1976 and continues through 1993. During the initial ten years, 1976 - 1985, the contaminant loadings are at double the rate of the loadings during the subsequent simulation period, 1986 - 1993. This pattern is intended to represent a continuous source throughout most of the first period and a decline associated with the discontinuance of disposal at the site throughout the late 1980s and 1990s. The continued loading at a diminished rate reflects the dissolution of residual contamination at and above the water table. The plume extends a distance of at least 1,400 feet, first towards the west-northwest and beyond this point toward the west-southwest. This is consistent with the direction of groundwater flow in the unconsolidated aquifer units.

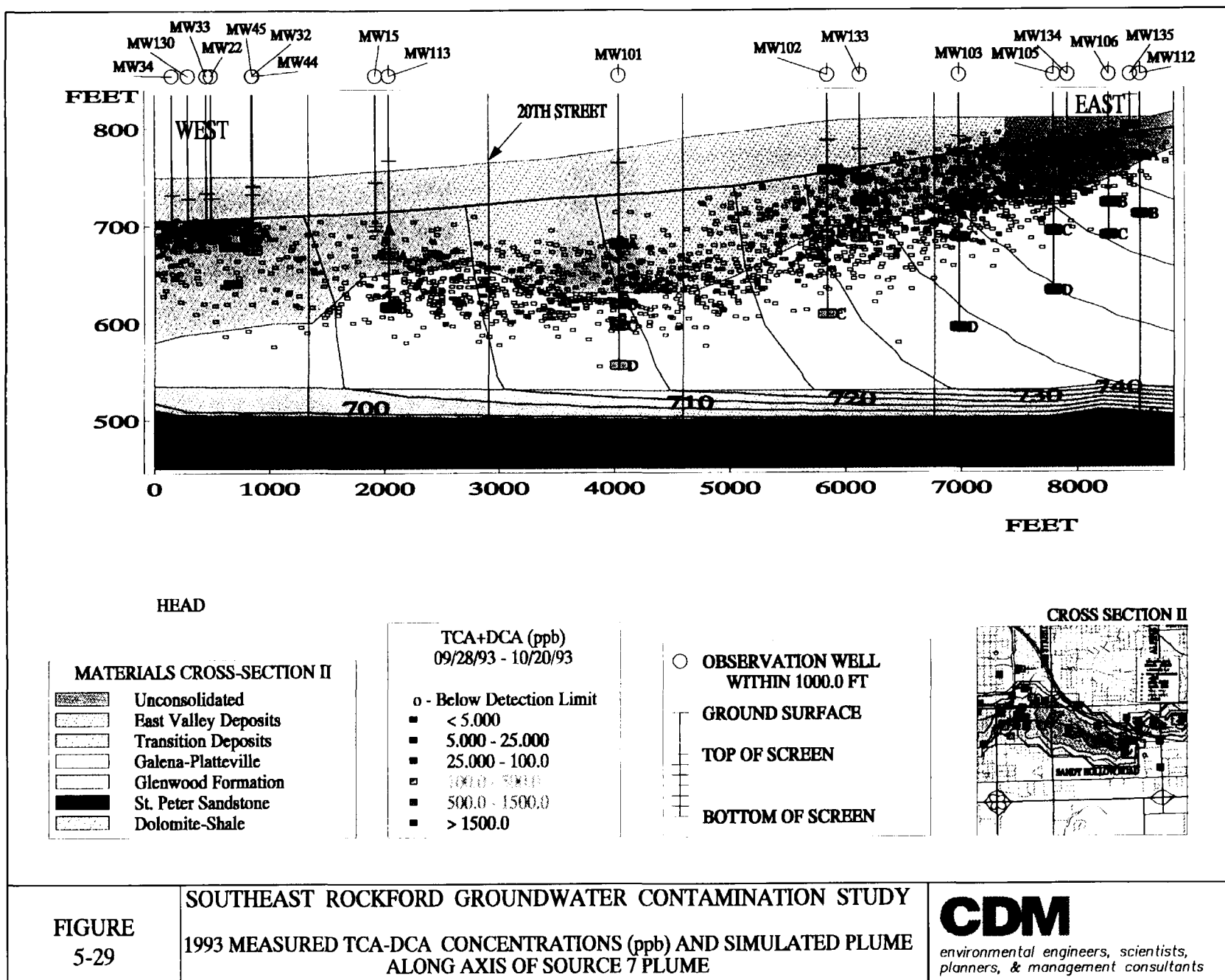
5.11.4 Source Area 14

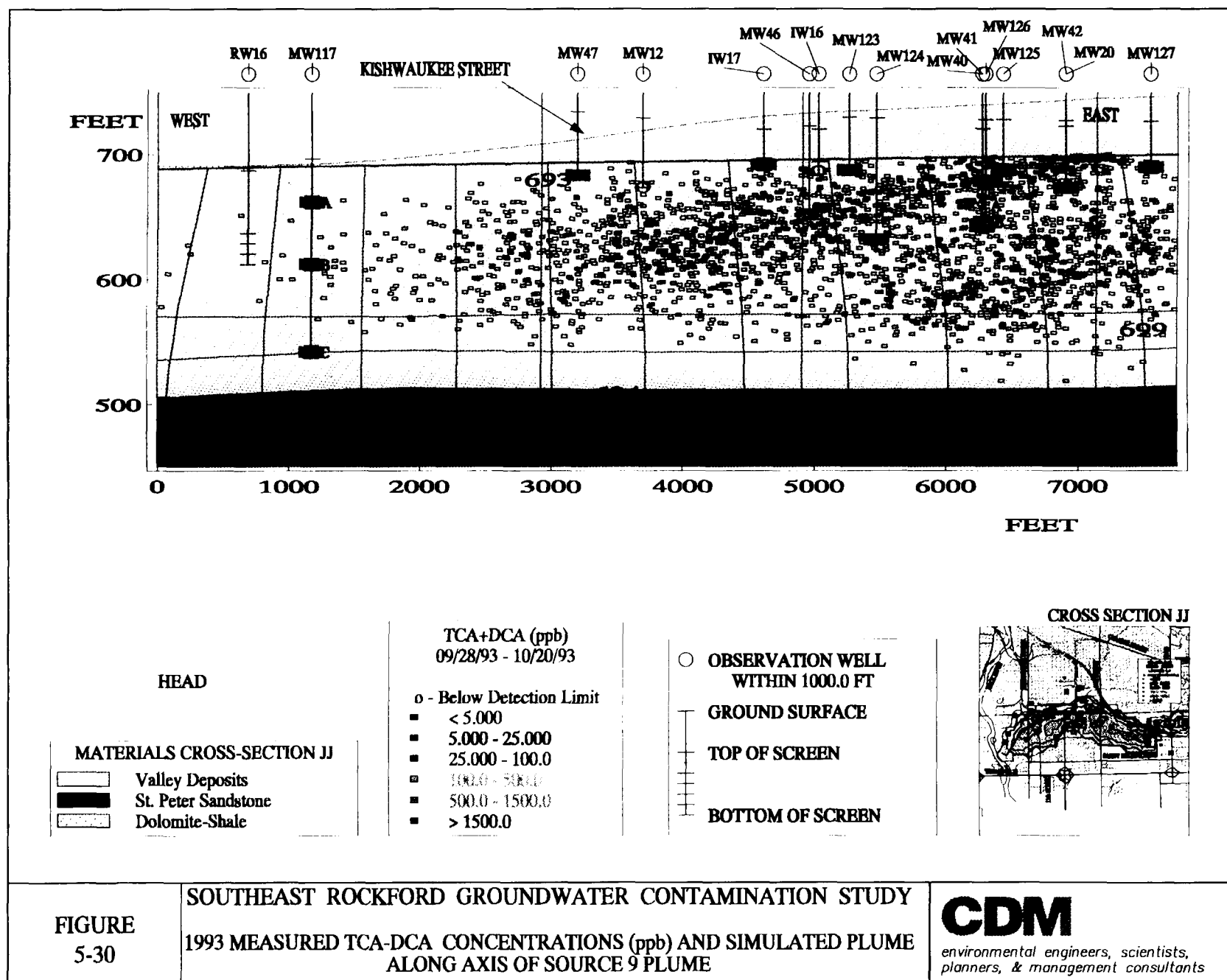
The absence of monitoring wells immediately downgradient of Source Area 14 makes it difficult to quantify the source loading history in this area.

5.11.5 Source Area 9/10

Figure 5-30 presents the simulated Source Area 9/10 plume on a cross section along the axis of the plume. The Source Area 9/10 plume starts directly upgradient of MW125 and MW126 and continues vertically downward and to the west as far as MW117. Based on the depth and magnitude of contamination of MW117C, it appears likely that Source Area 9/10 is the cause of contamination at this well. The upgradient portion of the Source Area 4 plume can also be seen on this cross-section, located below the Source Area 9/10 plume and extending laterally as far as MW124.

The exercise of calibrating the contaminant transport model has proven the model's ability to simulate the existing conditions, using transport parameters, source locations and loading rates which are consistent with everything known about the site. The presence of a non-aqueous phase plume downgradient of Source Area 8 has been raised as a means of explaining the near surface contamination at a significant distance from the plume. This hypothesis should be the subject of additional work to confirm the presence of a non-aqueous phase in this area. The model represents the current understanding of the system's behavior. As additional data is collected, it is important that the model be further refined to maintain consistency with that data thereby improving the model's predictive capacity.





5.11.6 Transport Mass Balance

As part of the transport simulations, the numerical model computes a mass balance of contaminant (TCA plus DCA) for the entire simulation period. For the calibration simulation, the mass balance at the end of the simulation is presented in Table 5-7.

5.11.7 Transport Sensitivity Analysis

Sensitivity analysis of transport parameters was done to assess uncertainty in the transport model. Parameters that were examined include source strength, dispersivity, retardation/effective porosity, and decay. Results of these simulations indicate that the transport model is somewhat insensitive to slight variations of the transport parameters. Details of the sensitivity analysis are given in Appendix M.

TABLE 5-7
Mass Balance for Calibrated Model

Component	Mass (kg)
Inflow from Sources	26,928
Discharged	62*
Lost by Decay	7,655
Remaining in System	19,211

*Includes 55 kg to UW35 and 7 kg to the Rock River

/

Section 6

Section
Six

Section 6.0

Human Health Risk Assessment

6.1 EXECUTIVE SUMMARY

This report contains a baseline human health risk assessment (HRA) of current and future exposures associated with residential water use at the Southeast Rockford Groundwater Contamination Site. The HRA is limited in scope to the evaluation of exposures associated with residential well use. Exposure to other media sampled, including soil, non-residential use groundwater, indoor air, and ambient air will not be addressed in this document, although additional risk assessments which address these exposures may be performed at all potential source areas in the future. The risk assessment addresses current and future site risks under baseline conditions, i.e., in the absence of remediation.

Residential dwellers are considered the only receptor group for this risk assessment, since residential water use is the only exposure scenario considered. Four exposure routes are considered in this scenario: (1) ingestion of residential well water; (2) dermal contact with residential well water through showering; (3) inhalation of contaminants which volatilized from residential well water in the household air; and (4) inhalation of contaminants which volatilized from residential well water during and immediately after showering. Risks associated with inhalation of indoor air potentially impacted by vapor migration from groundwater and/or soil will not be evaluated in the quantitative risk assessments. A discussion of indoor air data is presented in Section 4.0. Sampling and analysis data collected from each home are considered as separate data sets, and risk numbers are therefore derived separately for each residence.

Twenty-four residential wells were sampled in June, 1993 to determine if the groundwater contaminant plume had migrated into areas where the homes have not been connected to the city water supply. These wells served single-family homes with the exception of two wells located at 2131 Harrison which served Barrett's Trailer Park. These two wells are referred to throughout the report as 2131 Harrison A and B. There are 37 trailers and 5 homes at the trailer park. VOCs, including 1,1-DCE, 1,1-DCA, cis-1,2-DCE, trans-1,2-DCE, 1,2-DCA, TCA, TCE, and PCE were detected in 21 of the 24 residential wells.

For carcinogenic risks, USEPA has established a general 1E-04 to 1E-06 risk range as the target range within which the Agency attempts to manage risks. Thirteen of the twenty four wells sampled have a total carcinogenic risk within the risk range defined by the EPA. No homes have a total carcinogenic risk meeting or exceeding 1E-04, the upper limit of the EPA's target range.

Four wells have a total carcinogenic risk ranging from 1E-05 to 8E-05: 1726 Pershing, 1713 Harrison, and the two wells at 2131 Harrison. Inhalation is the dominant pathway contributing to exposure, but ingestion is the dominant pathway contributing to risk in each home. For each house the dominant chemical contributing to risk in all exposure routes is 1,1-DCE. In these homes 1,1-DCE had been detected in the 1993 sampling event.

Nine homes have a total carcinogenic risk ranging from $1\text{E-}06$ to $9\text{E-}06$. The dominant chemical contributing to risk in these homes is 1,1-DCE, however, in six of the seven homes where 1,1-DCE played a role in determining carcinogenic risk, the compound had not been detected in the 1993 sampling event, but is rather included in the risk assessment based on the detection of 1,1-DCE during the 1990 sampling event. Other chemicals which contributed to risk were PCE and TCE.

The wells at 1713 Harrison and 2131 Harrison Street have the largest number of different compounds detected, and also often have the largest concentrations of these compounds. The three wells also have the highest hazard indices for noncarcinogenic effects.

The hazard indices for each household are all below 1, indicating that non-cancerous or toxic human health effects from exposure to the groundwater at these residences is unlikely. There are three wells with a hazard index which exceeds $1\text{E-}01$ but is less than $3\text{E-}01$: the two wells at 2131 Harrison, and the well at 1713 Harrison. The compound cis-1,2-DCE is the dominant chemical contributing to the hazard indices for the ingestion and dermal exposure routes. The compound 1,1-DCE is the dominant chemical contributing to the hazard indices for the two inhalation exposure routes.

When detected chemicals are compared to the Safe Drinking Water Act MCLs only one MCL is exceeded, in the two wells located at 2131 Harrison. The MCL for trichloroethene is 0.005 mg/l , but TCE was detected in the two wells at 0.008 and 0.006 mg/l . MCLs only consider the route of ingestion, and may not be protective if additional chemical exposure occurs through another route.

Future concentrations of 1,1,1-TCA and 1,1-DCA in groundwater were assessed using the DYNTRACK contaminant transport code discussed previously in Section 5. Simulations estimating concentrations 70 years from the present were run for two conditions: 1) the contaminant sources remained at constant strength over the simulated time period, and 2) sources decayed exponentially during the simulation. Under either scenario, the residential wells along Harrison Avenue are expected to be contaminated in the future. Some deeper wells, those located in the northern regions of the area studied, may also be contaminated in the future. Estimated concentrations of the sum of TCA and 1,1-DCA range from 5 to 1500 ppb .

Among the different forms of uncertainty in the process of risk assessment (scenario uncertainty, parameter uncertainty, and model uncertainty), parameter uncertainty is the largest contributor. Parameter uncertainty refers to the assumptions and parameters used in concentration, dose, and risk calculations. There are two major sources of parameter uncertainty in this risk assessment. Since each household is subject to an individual risk characterization, the actual sample data collected at that household was used, eliminating the need to average the data, and possibly over-estimate or under-estimate the risk at each household. However, while this risk assessment considers compounds which had been detected at a particular house during the 1990 sampling event, but not detected at that house in 1993, in general, only the 1993 data set is used. The other major source of parameter uncertainty is the lack of oral and inhalation RfDs, and the lack of carcinogenicity slope factors for compounds which have not been adequately assessed. This prohibits the quantitative assessment of all the chemicals of concern, and may drive the overall

risk numbers below what they actually are. In some cases, values which were withdrawn from use, not recommended for general usage, or extrapolated from other routes were used in order to quantitatively evaluate as many of the chemicals of concern as possible, so that risk is not under-estimated by their omission. Therefore risk may be over-estimated or under-estimated due to use of an inaccurate value. In other cases, when use of an alternate value was deemed inappropriate, the chemical was not evaluated quantitatively, which may lead to an under-estimation of risk.

6.2 Introduction

This section of the report contains a baseline human health risk assessment (HRA) for current and future exposures associated with residential water use at the Southeast Rockford Groundwater Contamination Site. The sampling and analysis data employed in this assessment were collected from homes within the study area in June, 1993 and June, 1990. The June, 1993 data represent the primary database which was supplemented for specific purposes by the June, 1990 data.

6.2.1 General Problem at the Site

Volatile organic chemicals (VOCs), primarily chlorinated hydrocarbons, have been detected in both the bedrock and unconsolidated aquifers underlying the southeastern portion of Rockford, Illinois. At the time the contamination was first discovered in municipal wells in 1981, many residents of the area drew their water from private residential wells. Many residential wells have since been removed from service. Subsequent investigations which indicated that private residential wells were contaminated prompted a removal action initiated in 1989 by USEPA which included extending water mains and providing connection to city water for residences with private wells contaminated with VOCs at levels greater than 25% of the Removal Action Level (RAL). This was completed in December, 1990, with the connection of 283 residences. A second remedial action resulted from sampling for the Operable Unit performed by CDM under the direction of the IEPA, and resulted in the connection of an additional 264 homes to city water by November of 1991. Residents who were located outside of the hookup area were allowed to maintain their private well usage. These homes have been sampled in this Phase II work to determine if the groundwater contamination plume has since spread to these locations, and to determine the human health risks associated with detected contamination levels.

6.2.2 Site History

Groundwater contamination in the city of Rockford was initially discovered in 1981. In December of 1981, four municipal wells in the southeast portion of the city were removed from service due to the detection of VOCs. Additional city wells were removed from service in 1982 and 1985 due to the presence of VOCs. The Illinois Department of Public Health (IDPH) initiated more comprehensive well sampling in 1984, in response to an illegal dumping complaint. IDPH reported high levels of chlorinated solvents, and performed four additional sampling investigations in 1984, 1985, 1988, and 1989. Sampling by the Illinois State Water

Survey (ISWS) in 1986 also indicated the presence of VOCs in the groundwater. The USEPA Technical Assistance Team (TAT) also collected samples in 1989 and determined that chlorinated solvents were present in the groundwater.

The site was proposed for inclusion on the National Priorities List (NPL) in June of 1988, and was added to the NPL in March of 1989. A time-critical removal action was begun in 1989 by the USEPA, which included extending water mains and providing connections to city water for residences with private wells contaminated with VOCs at levels greater than 25% of the RAL. As an interim measure until these connections could be completed, residents whose private wells fit this criteria were offered bottled water and water filters. Connection of 264 homes was completed in December, 1991.

CDM, under the direction of the IEPA, sampled 117 groundwater wells (106 residential, 10 non-residential and 1 municipal) in June of 1990. This work was part of an Operable Unit, designated to provide an initial focus for the remedial investigation, and to expedite any ultimate removal actions, and will be referred to as the Operable Unit in this document. Residential well data collected during the operable unit investigation, as well as USEPA and IDPH data are presented in the Southeast Rockford Operable Unit Remedial Investigation Technical Memorandum (CDM, 1990). The June 1990 sampling was designed to determine which homes had contamination below the RAL, but above the Maximum Contaminant Levels (MCLs) defined in the Safe Drinking Water Act. Twenty-five of the 117 wells had contamination above the MCLs for at least one contaminant. The plume was defined as the area containing homes where an MCL of at least one target compound was exceeded. In some areas this also included a buffer zone, which was the area between a well with contamination above an MCL, and the next well with contamination below all MCLs. When residential wells on a particular block were found to be contaminated above an MCL, a water main was installed and all homes on that block were connected to the city water supply up to the next home sampled that did not exceed MCLs. This second removal action resulted in the connection of an additional 283 homes by November, 1992.

Phase II sampling, conducted by CDM, occurred from June 8 through June 10, 1993. Twenty-four residential wells (many of which were sampled during the earlier Operable Unit effort) were sampled to determine if the contaminant plume had migrated beyond its boundaries as determined in the operable unit, into areas where the homes have not yet been connected to the city water supply.

6.2.3 Scope and Objectives of the Risk Assessment

The risk assessment will be limited in scope to the evaluation of exposures associated with residential well use. The exposure routes typically considered for VOCs in groundwater include:

- ingestion via a domestic well;
- dermal contact during domestic use;

- inhalation during domestic use (through showering and through use for dishwashing, etc.);
- inhalation of indoor air contaminated via direct migration of vapors from groundwater into a residence.

Prior to initiation of the Phase II Remedial Investigation (RI), 547 residences with private wells were connected to the municipal water supply in the removal and remedial actions discussed in Section 6.2.1. The affected wells either showed exceedances of Maximum Contaminant Levels (MCLs) or were adjacent to contaminated wells and convenient enough to the extended main that the hookups were performed as a preventive measure. A qualitative risk assessment was conducted as part of the Operable Unit RI for these homes. Part of U.S. EPA risk assessment policy is to presume that exceedance of an MCL at a point of use of drinking water constitutes an unacceptable risk, providing justification for the early actions. U.S. EPA risk assessment guidance does not require a baseline risk assessment to consider previous risks that have been addressed by a completed response action. Additionally, the private wells located at residences that were connected to the municipal water supply were abandoned and could not be sampled in Phase II. For these reasons, this population was not considered in developing this risk assessment. However, given that the hookups were driven by levels of contamination higher than those evaluated quantitatively in this document, it can be safely assumed that risks from drinking the water from these wells would have proven unacceptable, if similarly evaluated.

Exposure to other media sampled, including soil, non-residential use groundwater, and ambient and indoor residential air will not be addressed in this document. Therefore, consideration of the last exposure route listed, inhalation of indoor air contaminated directly by vapor migration (as measured by the residential air sampling), will not be considered as part of the risk assessment, although it is discussed in Section 4.7 of this document. Additional risk assessments which address these exposures may be performed at all potential source areas in the future. This risk assessment will address current and future site risks under baseline conditions, i.e., in the absence of remediation. Carcinogenic risks and noncarcinogenic hazards associated with exposure to groundwater are assessed. The overall approach to the HRA is consistent with EPA guidance provided in the following documents:

- Exposure Factors Handbook. Office of Health and Environmental Assessment. 1989. EPA/600/8-89/043 (USEPA, 1989a);
- Human Health Evaluation Manual. Supplemental Guidance: "Standard Default Exposure Factors". Office of Emergency and Remedial Response. 1991. OSWER Directive 9285.6-03 (USEPA, 1991a);
- Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part A) Interim Final. Office of Emergency and Remedial Response. 1989. EPA/540/1-89/002 (USEPA, 1989b);
- Guidelines for Exposure Assessment. Federal Register Vol. 57, No. 104. Friday, May 29, 1992 (Federal Register, 1992);

- Integrated Risk Information System (IRIS). Office of Criteria and Standards. (October, 1993) (USEPA, 1993c);
- Health Effects Assessment Summary Tables (HEAST). Office of Emergency and Remedial Response. July 1993. EPA 540-R-93-058 (USEPA, 1992b);
- Guidance for Data Useability in Risk Assessment (Parts A and B). Office of Emergency and Remedial Response. 1992. Publications 9285.7-09A and 9285.7-09B (USEPA, 1992c).

A protocol document was prepared by CDM and submitted to IEPA and USEPA in order to obtain input and approval of the approach to this HRA. This document is provided as Appendix I. The following is a list of the issues and decisions relevant to the scope of this HRA:

- The cancer/noncancer risk estimate approach described in Risk Assessment Guidance for Superfund (RAGS) will be the only method employed to characterize risks.
- Only residential wells will be evaluated in the risk assessment. Risks associated with potential future exposure point concentrations at city wells west of the river will not be evaluated.
- Potential future risks resulting from the installation of new wells will not be evaluated.
- Toxicity summaries prepared by IEPA will be incorporated into the HRA.
- Ambient air data collected from test pit excavation activities, and residential air data collected inside homes located in Areas 4 and 7 will not be a part of this risk assessment, but may be addressed when Areas 4 and 7 are investigated as separate operable units.
- The soil data collected throughout the site will not be a part of the risk assessment, although soil data for Areas 4 and 7 may be addressed when Areas 4 and 7 are investigated as separate operable units.

The risk assessment provided herein is quantitative in nature. It is important to note the following limitations in the risk assessment process. A risk assessment cannot be used for any of the following purposes:

- to predict the actual incidence of adverse health effects;
- to establish any cause and effect relationship between site-specific contamination and specific health effects;
- to determine the number of excess cases of cancer or adverse systemic health effects in a neighborhood or population;

- to prove safe or unsafe conditions exist;
- to evaluate risk associated with unforeseeable future changes at a site;
- to preclude other legal liabilities even if risks are not significant.

Only residential dwellers are considered as a receptor group for this risk assessment, since residential water use is the only exposure pathway considered. Four exposure routes are considered in this scenario: (1) ingestion of residential well water; (2) dermal contact with residential well water through showering; (3) inhalation of contaminants which volatilize from residential well water in the household air; and (4) inhalation of contaminants which volatilize from residential well water during and immediately after showering. Sampling and analysis data collected from each home are considered as separate data sets, and risk numbers are therefore derived separately for each residence.

6.2.4 Organization of the Report

This report will include an evaluation of site data, a summary of the toxicological properties of the chemicals of interest, a discussion of the assumptions and calculations used for the exposure assessment, a characterization of the risks estimated to result from exposures at the sites, and a discussion of the uncertainties inherent in this risk assessment and the potential for over-estimation or under-estimation of risks. This HRA is organized in the following format, consistent with EPA HRA guidance:

Section 6.3, Data Evaluation - presents the data set used for the risk assessment and assesses the data useability for risk assessment.

Section 6.4, Toxicity Assessment - presents carcinogenic and noncarcinogenic toxicity values for the chemicals of concern, and discusses the use of surrogate route-specific data for chemicals lacking route-specific toxicity values.

Section 6.5, Exposure Assessment - discusses the physical setting, current and future exposed populations, and the potential exposure pathways. Exposure points and routes are identified and the calculations used to derive exposure point concentrations and estimated chemical intakes by each route are presented.

Section 6.6, Risk Characterization - presents a quantitative estimate of carcinogenic risks and noncarcinogenic hazards derived from the integration of exposure point concentrations with the available toxicity information. Health risks from all exposure routes are combined to present an overall risk due to site contaminants. This section also presents a comparison with the MCLs set by the Safe Drinking Water Act.

Section 6.7, Uncertainty Analysis - discusses sources of uncertainty in this particular risk assessment, and inherent in the process of risk assessment in general. The section will discuss scenario uncertainty, parameter uncertainty, and model uncertainty.

6.3 DATA EVALUATION

6.3.1 Summary of Available Data

The appendices to this Remedial Investigation Report contain all data collected during the Southeast Rockford Groundwater Contamination Study during the Phase I and Phase II investigations. Phase I data, consisting of soil and groundwater data, are presented in the Technical Memorandum for Phase I Field Activities (CDM, 1992) (Appendix D). Operable Unit data is not appended. Phase II data for residential well sampling are presented in Appendix H-7 of this document.

This remedial investigation focuses on the groundwater in the study area defined in Section 3. After consideration of all potential exposure pathways, residential wells are considered the first priority because residential use of groundwater is a complete pathway. This risk assessment therefore focuses on exposure to contaminated groundwater via residential wells. Additional media and associated exposure pathways may be considered at a later date.

6.3.1.1 Historical Data

Data have been collected from Southeast Rockford residential wells in a number of sampling events beginning in 1981. The early history of sampling efforts is detailed in the Southeast Rockford Operable Unit Remedial Investigation Technical Memorandum (CDM, 1990), which also presents data from the USEPA and the IDPH sampling rounds in 1989, and from the IEPA sampling performed by CDM in 1990.

This baseline risk assessment utilized results from the most current round of sampling to estimate risks. It is assumed that receptors are exposed to chemical concentrations reflected in the most current data for a 30-year period. In other words, conditions are assumed to be static over a 30-year period. Future conditions are evaluated qualitatively using a contaminant transport model. Due to the low concentrations generated by the model, quantitative estimates of future concentrations were not obtainable with a reasonable degree of certainty. The contamination plume is moving at a moderate to fast pace, so the data from the 1990 Operable Unit is not included unless it indicates the presence of a compound not detected in 1993. In this instance, these compounds are included as described in Section 6.5.4.1. Past data is also used to determine the presence of historical trends in contaminant migration. A comparison of sampling rounds performed by USEPA in 1989, IDPH in 1989, and IEPA in 1990 and 1993 is discussed in Section 6.3.5.

6.3.1.2 Residential Well Data

Phase II sampling, conducted by CDM, occurred from June 8 through June 10, 1993. Twenty-four residential wells (many of which were sampled during the Phase I effort) were sampled to determine if the contaminant plume had migrated beyond the boundaries determined in the

operable unit, into areas where the homes have not yet been connected to the city water supply. The homes from which samples were obtained are listed in Table 6-1. All wells sampled represent single family homes with the exception of the two wells sampled at 2131 Harrison. These wells serve the approximately 37 trailers and 5 homes at Barrett's Trailer Park. Figure 6-1 shows the location of these residences. The location of the residential well study area in relation to the source areas of the entire Southeast Rockford Groundwater Contamination Study Area is shown in Figure 4-1. The location of the residential well study area in relation to the concentration plume of specific compounds is shown in Figures 4-27 to 4-33. Samples were analyzed using Contract Laboratory Program (CLP) Special Analytical Services (SAS) drinking water detection limit methods for volatile organic compounds. VOCs were detected in 21 of the 24 residential wells. The following compounds were detected in the wells:

- methylene chloride
- 1,1-dichloroethene (1,1-DCE)
- 1,1-dichloroethane (1,1-DCA)
- cis-1,2-dichloroethene (cis-1,2-DCE)
- trans-1,2-dichloroethene (trans-1,2-DCE)
- chloroform
- 1,2-dichloroethane (1,2-DCA)
- 1,1,1-trichloroethane (TCA)
- trichloroethene (TCE)
- tetrachloroethene (PCE)

Four of these compounds (methylene chloride, trans-1,2-DCE, chloroform, and 1,2-DCA) were not detected above the contract required detection limit (CRDL). Complete data results are presented in Appendix H-7. A summary of the compounds detected and their frequency of detection in all of the residences is presented as Table 6-2. Concentrations for chemicals detected at each residence in the June 1993 sampling event represent exposure point concentrations employed in the estimation of risks attributable to ingestion of and dermal contact with the groundwater. Exposure point concentrations employed in the estimation of risks attributable to shower and household air inhalation are derived from the 1993 data as described in Section 6.5. The procedure for deriving exposure point concentrations for chemicals reported as "non-detects" that had been detected in the previous IEPA sampling event is discussed in Section 6.5.2.

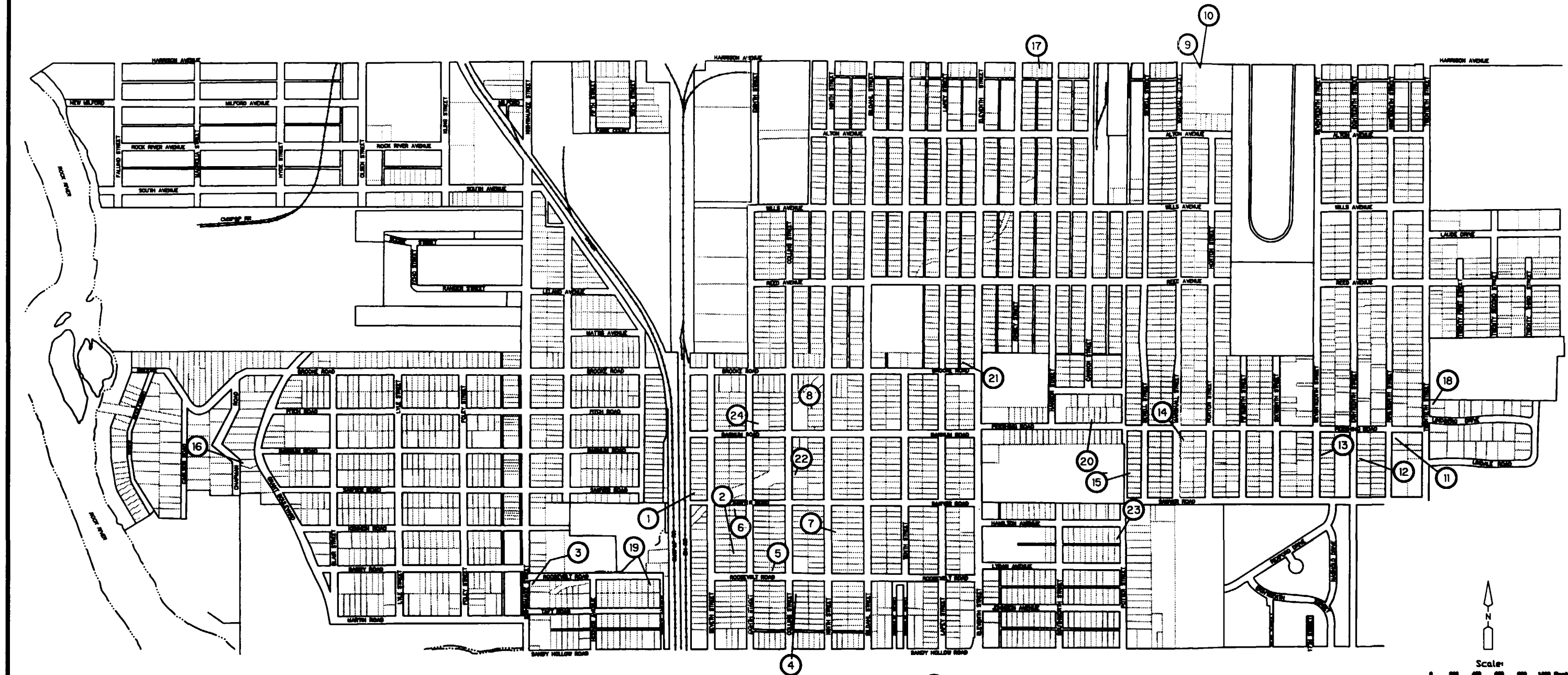
6.3.1.3 Modeling Data (Future Use)

Future site conditions are assessed using the DYNTRACK contaminant transport code, which models the transport of dissolved organic compounds in groundwater. Simulations were run 70 years into the future under two scenarios for TCA and 1,1-DCA, one assuming a constant-strength source, and the other assuming an exponentially decaying source. Input to the model included chemical data from groundwater samples collected from monitoring wells at the study area during the Phase II investigation. This data is described in Section 4.8 and presented in Appendices H9 - H11. Details of the contaminant transport model are given in section 5.0 of this report.

**TABLE 6-1
RESIDENTIAL WELL LOCATIONS**

House #	House Address
1	3115 7th Avenue
2	3237 8th Street
3	3302 Kishwaukee
4	3310 Collins
5	3245 Collins
6	3201 8th Street
7	3218 9th Street
8	3021 9th Street
9	2131 Harrison (A*)
10	2131 Harrison (B*)
11	3112 19th Street
12	3110 18th Street
13	3118 17th Street
14	3106 Marshall
15	3131 Sewell
16	3107 Grant Park
17	1713 Harrison
18	3024 20th Street
19	841 Roosevelt
20	1726 and 1730 Pershing
21	2955 11th Street
22	3126 Collins
23	1735 Hamilton
24	3028 8th Street

Notes: *Two wells located at Barrett's Mobile Home Park service 37 trailers and 5 homes.



(NO) RESIDENTIAL WELL LOCATIONS:

- | | | |
|--------------------|-----------------------|----------------------|
| 1. 3115 7th AVENUE | 9. 2131 HARRISON (a) | 17. 1713 HARRISON |
| 2. 3237 8th STREET | 10. 2131 HARRISON (b) | 18. 3024 20th STREET |
| 3. 3302 KISHWAUKEE | 11. 3112 19th STREET | 19. 841 ROOSEVELT |
| 4. 3310 COLLINS | 12. 3110 18th STREET | 20. 1716 PERSHING |
| 5. 3245 COLLINS | 13. 3118 17th STREET | 21. 2955 11th STREET |
| 6. 3201 8th STREET | 14. 3106 MARSHALL | 22. 3126 COLLINS |
| 7. 3218 9th STREET | 15. 3131 SEWELL | 23. 1735 HAMILTON |
| 8. 3021 9th STREET | 16. 3107 GRANT PARK | 24. 3028 8th STREET |

SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION STUDY

RESIDENTIAL WELL SAMPLING LOCATIONS

Table 6-2
CHEMICALS DETECTED IN RESIDENTIAL WELLS

Compound	Frequency of Detection (24 wells total)	Range of Detected Concentrations (µg/l)	Range of Detected Concentrations (mg/l)	Range of Detection Limits (µg/l)	MCL (mg/l)	Illinois Groundwater Quality Standards Class I (mg/l)
Methylene Chloride	2/24	0.2J - 0.4J	0.0002J - 0.0004J	2 - 10	-	-
1,1-Dichloroethene	5/24	0.3J - 5	0.0003J - 0.005	1 - 5	0.007	0.007
1,1-Dichloroethane	12/24	0.1J - 15	0.0001J - 0.015	1 - 5	-	-
C-1,2-Dichloroethene	5/24	1 - 10	0.001 - 0.010	1 - 5	0.07	0.07
Trans-1,2-Dichloroethene	1/24	0.2J	0.0002J	1 - 5	0.01	0.1
Chloroform	8/24	0.2J - 0.5J	0.0002J - 0.0005JD	1 - 5	0.10*	-
1,2-Dichloroethane	2/24	0.5J - 0.6J	0.0005J - 0.0006J	1 - 5	0.005	0.005
1,1,1-Trichloroethane	20/24	0.6J - 50D	0.0006J - 0.050D	1 - 5	0.2	0.2
Trichloroethene	20/24	0.2JB - 8	0.0002JB - 0.008	1 - 5	0.005	0.005
Tetrachloroethene	15/24	0.2J - 4	0.0002J - 0.004	1 - 5	0.005	0.005

Notes:

*: For trihalomethanes

Table does not include detections for field blanks, trip blanks, or duplicate samples.

J: Estimated Value

B: Blank Contamination

D: Dilution

6.3.2 Data Useability

6.3.2.1 Data Sources

The residential well data used in this risk assessment were collected as part of the Phase II sampling effort in June, 1993. The houses chosen were a subset of the houses which had been sampled in the Operable Unit in June, 1990, and had not been connected to the municipal water supply. The objective of this round of sampling was to determine whether the contaminant plume had expanded beyond its previous boundaries.

CDM also reviewed data collected from past sampling efforts, in an attempt to define any historical trends. This included data from the Operable Unit in 1990, and two sets of data collected by the USEPA and IDPH in 1989. QA/QC procedures, detection limits, and sample collection techniques were known for USEPA data but not for IDPH data. Additionally, USEPA, IDPH, and Operable Unit data were compared as part of the Operable Unit investigation, and discrepancies were found. Therefore, these data sets are presented strictly as supplementary historical information.

Groundwater data was collected from area monitoring wells. Additionally, CDM collected soil and air samples within the Phase II study area. Soil samples were not collected in the residential area under study in this risk assessment. Surface soil samples were collected in Area 4, which is immediately west of Barrett's Trailer Park at 2131 Harrison. The contamination detected in the surface soil at Area 4 may impact the residents at 2131 Harrison. According to standard practice, analytical sample data for each medium in the exposure area should be considered as part of the risk assessment; however, as directed by IEPA, this risk assessment will focus on the residential well data. Any conclusions drawn will be based on this limited scope.

6.3.2.2 Documentation

All sampling data was documented according to USEPA Contract Laboratory Program (CLP) procedures. Prior to the commencement of field work, methods were detailed in the Sampling and Analysis Plan (SAP) (CDM, 1993b) and Quality Assurance Project Plan (QAPP) (CDM, 1993a) for the Southeast Rockford Groundwater Contamination Site. The SAP includes information on the following items:

- sampling containers, preservation, holding times, packaging and shipment;
- sampling locations;
- sampling equipment and procedures for each medium;
- decontamination procedures for personnel, equipment, and sample bottles; and
- field quality control procedures.

The QAPP contains information on the following items:

- project scope and objectives, and organization;
- data quality objectives;
- quality assurance objectives for measurement data;

- sample custody;
- calibration procedures and frequencies;
- analytical procedures and services, and internal quality control checks;
- data reduction, validation and reporting;
- performance and system audits;
- preventative maintenance;
- corrective action.

All field activities were documented in field notebooks. Field notebooks contain daily entries on field activity, geologic and well installation information, daily weather and conditions, documentation on deviation or problems from the SAP, and monitoring information from on-site direct reading instruments.

All analytical data are maintained on USEPA forms for Routine Analytical Services (RAS) or SAS. Chain of Custody procedures were followed, including the use of sample labels, sample tags and formal chain-of-custody forms as defined in the QAPP. Samples were identified with information including time, date and location of sample.

Upon analysis, the laboratories which were used provided full sampling documentation including QC data from blanks, spikes, duplicates and standards. The laboratory packages also provided final custody documentation for the samples.

6.3.2.3 Analytical Methods and Detection Limits

Analytical methods to be used were specified in the QAPP. The analytical procedures for SAS CLP Laboratory analysis are specified in the SAS Client Request forms. Low concentration organics were analyzed using the SAS method based on USEPA CLP Statement of Work (SOW) OLCO1.0 (6/91) (CDM, 1993b). These SOWs also specify laboratory sample custody procedures, instrument calibration procedures, and frequency of calibration.

Detection limits were consistent with acceptable method detection limits. Samples were analyzed for VOCs at low detection levels to allow for comparison with drinking water standards. These detection limits ranged from 1 - 5 ppb, depending on the compound. Four samples required dilution, however, both the diluted and undiluted sample analyses were reported so comparisons to MCLs are still valid.

In order to use non-detects with confidence, the minimum method detection limit should be no more than 20% of the concentration of concern for a particular chemical. (EPA, 1992) This could not be achieved for vinyl chloride. The MCL for vinyl chloride is 2 ug/l, but the detection limit used is 1 ug/l. However, the method detection limits for analytical services from the CLP, while more than 20% of the MCL, are sufficiently low to allow for the comparison of the chemicals of concern with the MCLs.

6.3.2.4 Data Quality Indicators

There are five data quality indicators (DQIs) relevant to assessing data useability in a risk assessment:

- completeness
- comparability
- representativeness
- precision
- accuracy

CDM stated in the QAPP that the CLP is expected to provide data meeting quality control acceptance criteria for 95 percent or more of all samples tested. Analytical data from the CLP is assessed for contractual completeness by the Sample Management Office according to their contract compliance screening procedure. CDM reviews the data for precision, accuracy, and completeness in accordance with the procedures described in the National Functional Guidelines for Organic Data Review (USEPA, 1991b). This data is assessed according to five DQIs:

Completeness is a measure of the amount of valid data obtained compared to the amount that was expected to be obtained. All sample analyses resulting from the residential well sampling produced valid results. CDM originally proposed to sample 25 wells; 18 of these original 25 were sampled, 4 samples were collected from comparable alternate homes when the original home chosen was unavailable, and two additional homes were added to the list to better define the plume. Three samples from the original data set were therefore not sampled, and no alternates were chosen.

Comparability is a measure of the confidence associated with comparing one set of data to another. Comparability between Phase II data, and Operable Unit data is maintained by employing similar sampling procedures and utilizing appropriate quality assurance and quality control measures. Sampling was also performed at the same time of year, so seasonal variations would not influence the results. Upon review, CDM found relatively good correlation between Operable Unit and Phase II data. The issue of comparability between Operable Unit data, USEPA and IDPH data has been discussed in Southeast Rockford Operable Unit Remedial Investigation Technical Memorandum (CDM, 1990). It was found that many of the homes sampled during the Operable Unit and Phase II sampling events were not sampled during previous sampling rounds. Therefore, when available, this previous data is used only to determine possible historical patterns. Because the Operable Unit and Phase II data were comparable, some Operable Unit data was incorporated in the quantitative risk assessment, as described in Section 6.5.2.

Representativeness is a measure of the degree to which the data represents the actual site, and can serve as a measure of the actual risk at that site. With two exceptions, the residential well data in this study is only being used to represent the actual house at which the sample was taken. The samples collected are the water to which residents would have direct exposure. The data is therefore highly specific for each house.

Forty-two individual residences are served by the two wells located at the trailer park at 2131 Harrison. Because the contaminant profile and the detected concentrations in the two wells are essentially duplicative, the exposure concentrations estimated for these wells, and the risks associated with these exposure concentrations are considered representative of all forty-two residences. Since, in general, only one sample is used to estimate exposure point concentrations, it may not be representative of the actual exposure occurring at the house because it is not accounting for seasonal variations or laboratory variations which would be seen between a larger number of samples.

Precision is a measure of the agreement among separate measurements of the same item. This can be assessed from the duplicate and matrix spike analysis performed on the samples. Two duplicate samples (separate grab samples) were collected. In one set the compounds detected were identical. In the other sample, methylene chloride values differed by 40% (0.2 ppb versus 0.3 ppb), but all other compounds differed by no more than 22%. In addition, trans-1,2-dichloroethene was detected in one sample at 0.2 ppb, but not in the other sample. It was assigned a "J" qualifier. When performing the subsequent risk calculations on this residence, the highest of the two duplicate values for each compound was used as the representative concentration.

Accuracy is the degree of agreement of a data point with the true value. All data were analyzed according to USEPA CLP procedures, which included accuracy calculations derived from the percent recovery of spiked samples. This information was provided in the data packages provided from the lab. The internal standard area for one sample, 7572-07 (1713 Harrison) was out of control limits. All compounds for this sample were flagged with a "J" for estimation. When the same sample was diluted, all internal standard areas were acceptable. Internal standards were also out of control limits for 7572-20 (3021 9th Street). All positive results were qualified "J" for these samples.

All field blanks and trip blanks had positive results for target compounds. Methylene chloride (2 ug/l in 3 out of 3 samples), chloroform (32 ug/l, 25 ug/l, and 22 ug/l in 3 samples) and bromodichloromethane (4 ug/l in two samples and 3 ug/l in one sample) were detected in field blanks. TCE was detected in two out of 3 trip blanks at 0.5 ug/l, and in the remaining trip blank at 0.4 ug/l. Bromodichloromethane was not detected in any of the field investigative samples, so it was not evaluated any further. As discussed in National Functional Guidelines for Organic Data Review (USEPA, 1991b) and CLP SOW for Organics (USEPA, 1988) the sample results should be considered as positive results only if the concentrations in the sample exceed ten times the maximum amount detected in any blank. Under this scenario, methylene chloride was not detected in any field samples at concentrations greater than 20 ug/l (2 ug/l x 10), and therefore methylene chloride was eliminated as a chemical of concern. A similar procedure was employed for chloroform which is not a common laboratory contaminant. In this case when the blanks contain chemicals that are not common laboratory contaminants, the sample results should be considered as positive results if the concentration in the sample exceeds five times the maximum amount detected in any blanks. Chloroform was not detected in any field investigative sample at a concentration greater than five-fold over the field blank concentrations, and chloroform was eliminated as a contaminant of concern. Due to the likelihood that TCE

could exist as an actual contaminant in the samples, it was assessed in the quantitative risk assessment despite its presence in the trip blank samples.

6.3.2.5 Data Review

All residential well data was analyzed by Weyerhaeuser Analytical and Testing Services in Federal Way, Washington. Data reduction, evaluation and reporting was performed in accordance with USEPA Contract Laboratory Program specifications. CDM performed 25% data validation for all Southeast Rockford samples in accordance with the QAPP, in which a minimum of 25% of the samples in each Sample Delivery Group (SDG) was validated. Validation includes a check on holding times, chromatograms and instrument performance checks, blank analysis, surrogate recovery, matrix spike and duplicate analysis, internal standards, calibration, TCL identification and quantitation, and field QC. Appropriate qualifiers were assigned to data that could not be accepted without note. Samples in that SDG which were not among the 25% validated were assigned appropriate qualifiers when possible. The possible error in this is that some data may have been qualified unnecessarily, and other data may have been erroneously left unqualified. The following qualifiers were used in the validation effort:

"J": estimated because quantification in the sample or in the validation did not meet specifications;

"B": the compound was detected in an associated blank;

"D": the compound was detected in a diluted sample.

The potential effects of the use of qualified data will be addressed in the uncertainty portion of this document.

Following data validation by an independent data validator for laboratory parameters, the data was further reviewed by the remedial investigation data user for field parameters. At this stage, TCE concentrations under 1 ppb (which the data validator had qualified "J") were qualified with "U" by the data user due to the detection of TCE in the trip blank. For the purposes of the risk assessment however, we chose to follow the more conservative assumption by the data validator that TCE was present in the samples, even at levels below 1 ppb, in order to avoid underestimating risk.

6.3.2.6 Data Reports

Extensive historical information on the site was available for review, including the above-mentioned Southeast Rockford Operable Unit Remedial Investigation Technical Memorandum (CDM, 1990), Technical Memorandum for Phase I Field Activities (CDM, 1992), Sampling and Analysis Plan (SAP) (CDM, 1993b), and Quality Assurance Project Plan (QAPP) (CDM, 1993a). All data was provided to the validator with appropriate laboratory information.

6.3.2.7 Level of Certainty Associated with Analytical Data

There were few problems encountered during the collection, analysis, or validation of the residential well data, except with the problems described with the field and trip blank samples. Any problems which were encountered have been detailed above. Therefore, the analytical data can be used with a reasonable degree of certainty. The major concern is the use of one sample for each home, which may hide the natural variations that could be seen with a larger data set. The wells that were available to sample as background were limited because few wells were located outside of the contaminant plume but still within the study area.

6.3.3 Background Data

Background data is typically collected and used in a risk assessment to distinguish site-related contamination from naturally occurring or other non-site related levels of chemicals (RAGS, 1989). The chemicals of concern for this HRA consist of synthetic volatile organic compounds that are not naturally occurring so they should not be detected in background locations. The data set for this HRA includes residential wells located within an area of known groundwater contamination so it would be difficult to identify any true background locations prior to sampling. For these reasons, background locations were not used as selection criteria and all chemicals detected were included as chemicals of concern.

There are three homes where no compounds were detected in the 1993 sampling: 3131 Sewell, 3107 Grant Park, and 3201 8th Street. Of these homes, 3131 Sewell and 3107 Grant Park are not addressed in the quantitative portion of the risk assessment. The well at 3201 8th Street is included however because TCA was detected during the 1990 round of sampling.

6.3.4 Selection of Chemicals of Concern

Except for methylene chloride and chloroform, all chemicals which were detected in the field samples are included as chemicals of concern (COCs). Methylene chloride and chloroform were excluded from consideration as chemicals of concern due to their presence in blank samples, as explained in Section 6.3.2.4.

6.3.5 Historical Trends

The data collected from the 1989 USEPA and IDPH sampling rounds, the data collected from the 1990 IEPA/CDM Operable Unit sampling, and the 1993 Phase II data are presented in Table 6-3. The data sets are presented per residence in an attempt to determine if there are any historical trends which can be determined from data collected at each house over time. Fifteen

TABLE 6-3
HISTORICAL RESIDENTIAL WELL SAMPLING RESULTS

House Address:	1726 Pershing						
Sampling Date:	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990		June, 1993		Frequency of Detection
Sampling Agency:			IEPA		IEPA		
			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	NS	2.1 B	0.50	2	1	2/2
1,1,1-Trichloroethane	NS	NS	4.1	0.50	5	1	2/2
cis-1,2-Dichloroethene	NS	NS	0.5 J	0.50	2	1	2/2
1,1-Dichloroethane	NS	NS	0.5 J	0.50	1	1	2/2
1,1-Dichloroethene	NS	NS	0.4 J	0.50	0.6 J	1	2/2
Tetrachloroethene	NS	NS	ND	0.50	0.4 J	1	1/2

House Address:	2955 11th Street						
Sampling Date:	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990		June, 1993		Frequency of Detection
Sampling Agency:			IEPA		IEPA		
			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	NS	1	0.50	1 JB	1	2/2
1,1,1-Trichloroethane	NS	NS	1.3 U	0.50	2	1	2/2
cis-1,2-Dichloroethene	NS	NS	11.2	0.50	1	1	2/2
trans-1,2-Dichloroethene	NS	NS	0.1 J	0.50	ND	1	1/2
1,2-Dichloroethane	NS	NS	0.1 J	0.50	ND	1	1/2
1,1-Dichloroethane	NS	NS	0.1 J	0.50	0.9 J	1	2/2
1,1-Dichloroethene	NS	NS	0.1 J	0.50	0.3 J	1	2/2

House Address:	3126 Collins						
Sampling Date:	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990		June, 1993		Frequency of Detection
Sampling Agency:			IEPA		IEPA		
			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	NS	2.0 B	0.50	1	1	2/2
1,1,1-Trichloroethane	NS	NS	2.9 B	0.50	2	1	2/2
Tetrachloroethene	NS	NS	ND	0.50	0.4 J	1	1/2

House Address:	3107 Grant Park						
Sampling Date:	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990		June, 1993		Frequency of Detection
Sampling Agency:			IEPA		IEPA		
			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Nothing Detected	NS	NS	ND	0.50	ND	1	0/2

Notes:

All concentrations in ug/l
 Information on detection limits used for IDPH and USEPA analysis is not available
 ND: Not detected above detection limit
 NS: House not sampled
 NA: Not analyzed
 NAP: Not applicable
 U: Not detected in dilution
 J: Estimated value
 B: Blank contamination

TABLE 6-3 (continued)
HISTORICAL RESIDENTIAL WELL SAMPLING RESULTS

House Address:	1713 Harrison						
Sampling Date:	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990		June, 1993		Frequency of Detection
Sampling Agency:			IEPA		IEPA		
			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	NS	3.3	0.50	4 JD	1	2/2
1,1,1-Trichloroethane	NS	NS	33.4	0.50	50 D	1	2/2
cis-1,2-Dichloroethene	NS	NS	5.8	0.50	8 D	1	2/2
trans-1,2-Dichloroethene	NS	NS	0.1 J	0.50	ND	1	1/2
1,1-Dichloroethane	NS	NS	8.0	0.50	9 D	1	2/2
1,1-Dichloroethene	NS	NS	1.5	0.50	2 JD	1	2/2
Tetrachloroethene	NS	NS	0.7 B	0.50	0.8 JD	1	2/2
Chloroform	NS	NS	ND	0.50	0.5 JD	1	1/2

House Address:	3024 20th Street						
Sampling Date:	USEPA Sample Concentration	November, 1989 IDPH Sample Concentration	June, 1990		June, 1993		Frequency of Detection
Sampling Agency:			IEPA		IEPA		
			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	0.9	NS	NAP	0.6 JB	1	2/2
1,1,1-Trichloroethane	NS	0.6	NS	NAP	0.6 J	1	2/2
Tetrachloroethene	NS	ND	NS	NAP	0.3 J	1	1/2

House Address:	841 Roosevelt						
Sampling Date:	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990		June, 1993		Frequency of Detection
Sampling Agency:			IEPA		IEPA		
			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	NS	0.9 B	0.50	1 JB	1	2/2
1,1,1-Trichloroethane	NS	NS	2.4	0.50	2	1	2/2
cis-1,2-Dichloroethene	NS	NS	0.1 J	0.50	ND	1	1/2
1,1-Dichloroethane	NS	NS	0.3 J	0.50	0.2 J	1	2/2
1,1-Dichloroethene	NS	NS	0.2 J	0.50	ND	1	1/2
Tetrachloroethene	NS	NS	2.4 B	0.50	3	1	2/2
Chloroform	NS	NS	ND	0.50	0.3 J	1	1/2

Notes:

All concentrations in ug/l
Information on detection limits used for IDPH and USEPA analysis is not available
ND: Not detected above detection limit
NS: House not sampled
NA: Not analyzed
NAP: Not applicable
U: Not detected in dilution
J: Estimated value
B: Blank contamination

TABLE 6-3 (continued)
HISTORICAL RESIDENTIAL WELL SAMPLING RESULTS

House Address:	3115 7th Avenue						
Sampling Date:	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
Sampling Agency:			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	NS	1.1 B	0.50	0.6 JB	1	2/2
1,1,1-Trichloroethane	NS	NS	3	0.50	1	1	2/2
cis-1,2-Dichloroethene	NS	NS	0.1 J	0.50	ND	1	1/2
Tetrachloroethene	NS	NS	1.3 B	0.50	0.6 J	1	2/2

House Address:	3237 8th Street						
Sampling Date:	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
Sampling Agency:			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	NS	1	0.50	1	1	2/2
1,1,1-Trichloroethane	NS	NS	1.5 U	0.50	2	1	2/2
1,1-Dichloroethane	NS	NS	0.2 J	0.50	0.2 J	1	2/2
1,1-Dichloroethene	NS	NS	0.1 J	0.50	ND	1	1/2
Tetrachloroethene	NS	NS	1.8	0.50	4	1	2/2
Chloroform	NS	NS	ND	0.50	0.3 J	1	1/2

House Address:	3302 Kishwaukee						
Sampling Date:	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
Sampling Agency:			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
1,1,1-Trichloroethane	NS	NS	2.5	0.50	1	1	2/2
Tetrachloroethene	NS	NS	1.2 B	0.50	1	1	2/2

House Address:	3310 Collins						
Sampling Date:	USEPA Sample Concentration	December, 1989 IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
Sampling Agency:			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	0.9	0.9 B	0.50	0.6 JB	1	3/3
1,1,1-Trichloroethane	NS	2.2	2.5	0.50	1	1	3/3
1,1-Dichloroethane	NS	Trace	0.1 J	0.50	ND	1	2/3
1,1-Dichloroethene	NS	ND	0.1 J	0.50	ND	1	1/3
Tetrachloroethene	NS	Trace	ND	0.50	0.3 J	1	2/3

Notes:

All concentrations in ug/l

Information on detection limits used for IDPH and USEPA analysis is not available

ND: Not detected above detection limit

NS: House not sampled

NA: Not analyzed

NAP: Not applicable

U: Not detected in dilution

J: Estimated value

B: Blank contamination

TABLE 6-3 (continued)
HISTORICAL RESIDENTIAL WELL SAMPLING RESULTS

House Address:	3245 Collins						
Sampling Date:	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
Sampling Agency:			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	NS	ND	0.50	0.3 JB	1	1/2
1,1,1-Trichloroethane	NS	NS	1.0 U	0.50	0.7 J	1	2/2
1,1-Dichloroethane	NS	NS	0.1 J	0.50	ND	1	1/2
Tetrachloroethene	NS	NS	0.5 J	0.50	0.3 J	1	2/2
Chloroform	NS	NS	ND	0.50	0.2 J	1	1/2

House Address:	3201 8th Street						
Sampling Date:	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
Sampling Agency:			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
1,1,1-Trichloroethane	NS	NS	0.6 U	0.50	ND	1	1/2

House Address:	3218 9th Street						
Sampling Date:	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
Sampling Agency:			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	NS	NS	NAP	2 JB	1	1/1
1,1,1-Trichloroethane	NS	NS	NS	NAP	2	1	1/1
1,1-Dichloroethane	NS	NS	NS	NAP	0.2 J	1	1/1
Tetrachloroethene	NS	NS	NS	NAP	0.3 J	1	1/1
Chloroform	NS	NS	NS	NAP	0.2 J	1	1/1

House Address:	3021 9th Street						
Sampling Date:	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
Sampling Agency:			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	ND	NS	NS	NAP	1 JB	1	1/2
1,1,1-Trichloroethane	3.0 J	NS	NS	NAP	2 J	1	2/2
1,1-Dichloroethane	ND	NS	NS	NAP	0.5 J	1	1/2

Notes:

All concentrations in ug/l

Information on detection limits used for IDPH and USEPA analysis is not available

ND: Not detected above detection limit

NS: House not sampled

NA: Not analyzed

NAP: Not applicable

U: Not detected in dilution

J: Estimated value

B: Blank contamination

TABLE 6-3 (continued)
HISTORICAL RESIDENTIAL WELL SAMPLING RESULTS

House Address: Sampling Date: Sampling Agency:	2131 Harrison (A)						
	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Methylene Chloride	NS	NS	NS	NAP	0.3 J	2	1/1
Trichloroethene	NS	NS	NS	NAP	8	1	1/1
1,1,1-Trichloroethane	NS	NS	NS	NAP	18	1	1/1
cis-1,2-Dichloroethene	NS	NS	NS	NAP	10	1	1/1
trans-1,2-Dichloroethene	NS	NS	NS	NAP	0.2 J	1	1/1
1,2-Dichloroethane	NS	NS	NS	NAP	0.6 J	1	1/1
1,1-Dichloroethane	NS	NS	NS	NAP	15	1	1/1
1,1-Dichloroethene	NS	NS	NS	NAP	5	1	1/1
Tetrachloroethene	NS	NS	NS	NAP	0.9 J	1	1/1
Chloroform	NS	NS	NS	NAP	0.5 J	1	1/1

House Address: Sampling Date: Sampling Agency:	2131 Harrison (B)						
	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Methylene Chloride	NS	NS	NS	NAP	0.4 J	2	1/1
Trichloroethene	NS	NS	NS	NAP	6	1	1/1
1,1,1-Trichloroethane	NS	NS	NS	NAP	18	1	1/1
cis-1,2-Dichloroethene	NS	NS	NS	NAP	9	1	1/1
1,2-Dichloroethane	NS	NS	NS	NAP	0.5 J	1	1/1
1,1-Dichloroethane	NS	NS	NS	NAP	13	1	1/1
1,1-Dichloroethene	NS	NS	NS	NAP	4	1	1/1
Tetrachloroethene	NS	NS	NS	NAP	0.7 J	1	1/1
Chloroform	NS	NS	NS	NAP	0.4 J	1	1/1

Notes:

All concentrations in ug/l
Information on detection limits used for IDPH and USEPA analysis is not available
ND: Not detected above detection limit
NS: House not sampled
NA: Not analyzed
NAP: Not applicable
U: Not detected in dilution
J: Estimated value
B: Blank contamination

TABLE 6-3 (continued)
HISTORICAL RESIDENTIAL WELL SAMPLING RESULTS

House Address:	3110 18th Street						
Sampling Date:	USEPA Sample Concentration	December, 1989 IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
Sampling Agency:			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	ND	ND	0.50	0.2 JB	1	1/3
1,1,1-Trichloroethane	NS	ND	3.2 U	0.50	0.7 J	1	2/3
trans-1,2-Dichloroethene	NS	2.2	ND	0.50	ND	1	1/3
1,1-Dichloroethane	NS	ND	0.1 J	0.50	ND	1	1/3
1,1-Dichloroethene	NS	ND	0.2 J	0.50	ND	1	1/3
Chloroform	NS	ND	ND	0.50	0.3 J	1	1/3

House Address:	3118 17th Street						
Sampling Date:	USEPA Sample Concentration	October, 1989 IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
Sampling Agency:			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	1.3	NS	NS	NAP	0.9 JB	1	2/2
1,1,1-Trichloroethane	2.5	NS	NS	NAP	1	1	2/2
1,1-Dichloroethane	ND	NS	NS	NAP	0.1 J	1	1/2
Tetrachloroethene	NA	NS	NS	NAP	0.2 J	1	1/1

House Address:	3106 Marshall						
Sampling Date:	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
Sampling Agency:			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	NS	ND	0.50	0.2 JB	1	1/2
1,1-Dichloroethane	NS	NS	0.2 J	0.50	0.2 J	1	2/2
1,1-Dichloroethene	NS	NS	0.1 J	0.50	ND	1	1/2

House Address:	3131 Sewell						
Sampling Date:	USEPA Sample Concentration	October, 1989 IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
Sampling Agency:			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Nothing Detected	ND	NS	NS	NAP	ND	1	0/2

Notes:

All concentrations in ug/l
Information on detection limits used for IDPH and USEPA analysis is not available
ND: Not detected above detection limit
NS: House not sampled
NA: Not analyzed
NAP: Not applicable
U: Not detected in dilution
J: Estimated value
B: Blank contamination

TABLE 6-3 (continued)
HISTORICAL RESIDENTIAL WELL SAMPLING RESULTS

House Address: Sampling Date: Sampling Agency:	3112 19th Street						
	October, 1989 USEPA Sample Concentration	IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	0.8	NS	NS	NAP	0.6 JB	1	2/2
1,1,1-Trichloroethane	1.1	NS	NS	NAP	0.6 J	1	2/2
Tetrachloroethene	NA	NS	NS	NAP	0.2 J	1	1/1

House Address: Sampling Date: Sampling Agency:	1735 Hamilton						
	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	NS	0.8	0.50	0.6 JB	1	2/2
1,1,1-Trichloroethane	NS	NS	1.3 U	0.50	0.8 J	1	2/2
1,1-Dichloroethane	NS	NS	0.1 J	0.50	ND	1	1/2
1,1-Dichloroethene	NS	NS	0.1 J	0.50	ND	1	1/2

House Address: Sampling Date: Sampling Agency:	3028 8th Street						
	USEPA Sample Concentration	IDPH Sample Concentration	June, 1990 IEPA		June, 1993 IEPA		Frequency of Detection
			Sample Concentration	Detection Limit	Sample Concentration	Detection Limit	
Trichloroethene	NS	NS	NS	NAP	0.5 JB	1	1/1
1,1,1-Trichloroethane	NS	NS	NS	NAP	1	1	1/1
1,1-Dichloroethane	NS	NS	NS	NAP	0.5 J	1	1/1

Notes:

All concentrations in ug/l

Information on detection limits used for IDPH and USEPA analysis is not available

ND: Not detected above detection limit

NS: House not sampled

NA: Not analyzed

NAP: Not applicable

U: Not detected in dilution

J: Estimated value

B: Blank contamination

of the wells had been sampled in 1990; seven of the wells had been sampled by either IDPH or USEPA in 1989. Five of the wells had not been sampled previously.

In every case, chemicals detected above CRDL in the 1990 sampling round were also detected in the 1993 round, although in some cases concentrations in 1993 were estimated or "J" values. Sample concentrations above CRDL increased at only one home, 1713 Harrison. At the same home, chemicals detected at estimated concentrations in 1990 were detected above CRDL in 1993. In nine homes, chemicals reported as non-detects in 1990 were reported as estimated, or "J" values in 1993. However, chemicals reported as non-detects in 1990 were never detected above CRDL in 1993. In ten homes, chemicals detected as estimated values in 1990 were reported as non-detects in 1993. In five homes, chemicals reported as estimated values in 1990 were also reported as estimated values in 1993, typically at the same estimated concentration. The only trend evident from the limited data is the increase in sample concentrations at 1713 Harrison. This area is downgradient of Area 4, and represents a possible enlargement of plume boundaries. Total VOC concentrations detected in the homes in 1990 and 1993 are shown on Figure 4-22.

The environmental chemistry of the chemicals of concern, including their degradation products, is discussed in Sections 4.8 and 4.9 of this report.

6.4 Toxicity Assessment

This section provides the toxicological properties of the selected chemicals of concern using the most current available toxicological information. Chemical information sheets for the chemicals of concern prepared by the IEPA Office of Chemical Safety are presented in Appendix J. A summary table of this information, presenting the health effects of exposures to these chemicals, is provided as Table 6-4. These health effects are related to exposure concentrations for each chemical. The two types of toxicity values which are used to quantify the toxic effects of a chemical on human health include a chemical's cancer slope factor (SF) and reference dose (RfD). Many of the cancer slope factors and RfDs used in this assessment were obtained from USEPA's Integrated Risk Information System (IRIS) (USEPA, 1993c). IRIS provides chemical-specific risk information that represents an EPA scientific consensus. The quantitative risk estimates in IRIS have been reviewed and agreed upon by scientists across the Agency using available studies on a chemical. Slope factors and RfDs were also obtained from EPA's Health Effects Summary Tables (HEAST), Annual, 1993 (USEPA, 1992b) in the absence of IRIS data. Some values which were not listed in either of these two databases were obtained from the EPA Environmental Criteria and Assessment Office (ECAO) (USEPA, 1991c, 1992d, 1992e, 1993b). Some quantitative information on each chemical was available through one of the above mentioned sources; however, in many instances, particular data was lacking on the chemicals.

6.4.1 Carcinogens

USEPA has developed a qualitative weight-of-evidence classification system to define a chemical's potential to cause a carcinogenic effect based on the extent of available data indicating that an agent is a human carcinogen. This classification system is based on carcinogenicity

TABLE 6-4
HEALTH EFFECTS OF CHEMICALS OF CONCERN

Compound	Short-term Exposure Health Effects	Long-term Exposure Health Effects	Reproductive Toxicity	Mutagenicity	Carcinogenicity Classification
Dichloroethanes (1,2-Dichloroethane, 1,1-Dichloroethane)	Headache, dizziness, weakness nausea, chest pains, diarrhea, unconsciousness heart, lung, liver damage; eye, nose, throat irritation	Nausea, vomiting, weakness; gastrointestinal problems; liver, kidney, heart diseases	-	-	1,2-DCA: B2 1,1-DCA: C *
Dichloroethylenes (1,1-Dichloroethene, cis-1,2-Dichloroethene trans-1,2-Dichloroethene)	Central nervous system depression; nausea, vomiting, stomach cramps; eye irritation, damage	Liver and kidney damage	1,1-DCE: no evidence cis-1,2-DCE, trans-1,2-DCE: no data	1,1-DCE: positive cis-1,2-DCE, trans-1,2-DCE: negative	1,1-DCE: C cis-1,2-DCE: D * trans-1,2-DCE: no data
Tetrachloroethene	Central nervous system depression; dizziness, headache, nausea; mental, physical impairments; eye, nose, throat irritation	Frequent dizziness, headaches. nausea; fatigue, disorientation; short-term memory deficits; muscle incoordination; leukemia (animals)	-	Weakly mutagenic	C - B2 **
1,1,1-Trichloroethane	Eye, nose, throat irritation; respiratory arrest and shock; mild liver, kidney effects; skin irritation	Minor liver effects (animals)	Non-fatal delays in fetal development (animals)	-	D *
Trichloroethene	Eye, nose, throat irritation; skin burning, irritation, damage; central nervous system depression; nausea, dizziness, tremors; headache, confusion;	Nausea, dizziness, headaches; impaired short-term memory; muscular incoordination; confusion, reduced reasoning	No evidence of toxicity to embryo	Weakly mutagenic	C - B2 **

Notes:

Information from the IEPA Office of Chemical Safety unless otherwise noted

*: Information obtained from IRIS database

**: Information obtained from: U.S.EPA. Carcinogenicity Characterization of TCE, PCE, and Styrene. Environmental Criteria and Assessment Office (ECAO). 5/18/92.

results from long-term animal tests, epidemiological studies, and other supportive data. As presented in Table 6-5, USEPA separates chemicals into five distinct categories, ranging from Group A, chemicals for which there is sufficient evidence to consider the chemical carcinogenic to humans, to Group E, chemicals for which there is evidence of noncarcinogenicity in humans. Chemicals which have been classified in Groups A through C are included in the quantitative risk assessment if slope factors are available (or could be derived).

Cancer slope factors are calculated by USEPA's Carcinogen Assessment Group (CAG) and verified by the Carcinogen Risk Assessment Verification Endeavor Workgroup (CRAVE). The slope factor is a 95% upper-bound estimate of the slope of the dose /response curve for a particular study or group of studies involving the exposure of humans or animals. When available, these slope factors (as presented in Table 6-6) are used to estimate the risks associated with exposure to potential carcinogens. Slope factors are currently only available for the oral and inhalation routes of exposure. In this risk assessment, oral slope factors are used to quantify risks associated with dermal contact. This approach follows guidance provided in RAGS (EPA, 1989). Unit risks, or the risks associated with lifetime exposure to 1 ug/l of a chemical in drinking water or 1 ug/m³ of a chemical in air can be used to derive slope factors according to the following equations:

$$\text{risk per ug/m}^3 \text{ (air)} = \text{slope factor (risk per mg/kg/day)} \times 1/70 \text{ kg} \times 20 \text{ m}^3/\text{day} \times 10^{-3} \text{ (mg/ug)}$$

$$\text{risk per ug/l (water)} = \text{slope factor (risk per mg/kg/day)} \times 1/70 \text{ kg} \times 2 \text{ l/day} \times 10^{-3} \text{ (mg/ug)}$$

When verified slope factors are not available from IRIS or HEAST, unit risk values are used to derive slope factors. Inhalation slope factors are derived from unit risk values for 1,1-dichloroethene and 1,2-dichloroethane.

One chemical, trans-1,2-DCE, has not been evaluated for carcinogenicity. Two compounds, cis-1,2-DCE, and TCA, are listed as "D" carcinogens, and are therefore not evaluated quantitatively. Two chemicals, 1,1-DCE and 1,1-DCA, are classified as level "C" carcinogens; there is no information available to evaluate 1,1-DCA quantitatively.

6.4.2 Noncarcinogens

A chronic RfD is defined as an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of harmful effects during a lifetime exposure. The chronic RfDs, derived by USEPA's RfD Workgroup, are specifically developed to be protective of long-term exposure to a compound. An RfD is typically derived by applying a safety factor of one or more orders of magnitude to a dose thought to represent a no observed adverse effect level (NOAEL) in humans. The magnitude of the uncertainty factors that are applied when developing an RfD is dependent on the quality and applicability of the available animal and human toxicity studies. Table 6-7 presents the RfDs used in calculating hazards associated with exposure to noncarcinogens.

TABLE 6-5
WEIGHT OF EVIDENCE CLASSIFICATION

Group	Description
A	Human carcinogen
B1 or B2	Probable human carcinogen
	B1 indicates limited human data are available
	B2 indicates sufficient evidence in animals whereas inadequate or no evidence in humans
C	Possible human carcinogen
D	Not classifiable as to human carcinogenicity
E	Evidence of noncarcinogenicity for humans

Source: U.S. EPA. 1989. Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part A). Interim Final. EPA/540/1-89/002.

TABLE 6-6
TOXICITY VALUES FOR CHEMICALS OF CONCERN
CARCINOGENS

Chemical	Oral Slope Factor (mg/kg/day) ⁻¹	Weight of Evidence	Tumor Site	Ref.	Inhalation Slope Factor (mg/kg/day) ⁻¹	Weight of Evidence	Tumor Site	Ref.
1,1-Dichloroethene	6.0E-01	C	adrenal	(1)	1.75E-01	C	kidney	(2)
1,1-Dichloroethane	NA	C	liver, mammary, hemangiosarcoma	(1)	NA	C	-	(1)
cis-1,2-Dichloroethene	NA	D	-	(1)	NA	D	-	(1)
trans-1,2-Dichloroethene	NE	D (8)	-	(7)	NE	D (8)	-	(7)
1,2-Dichloroethane	9.1E-02	B2	circulatory system	(1)	9.1E-02 (4)	B2	circulatory system	(1)
1,1,1-Trichloroethane	NA	D	-	(1)	NA	D	-	(1)
Trichloroethene	1.1E-02	C - B2 (6)	-	(3)	6.0E-03	C - B2 (6)	-	(3)
Tetrachloroethene	5.2E-02	C - B2 (6)	-	(3)	2.0E-03	C - B2 (6)	-	(3)

- (1): EPA, 1994, Integrated Risk Information System (IRIS). On-line database
- (2): EPA, 1994. Environmental Criteria and Assessment Office (ECAO). Risk Assessment Issue Paper for: Provisional Inhalation Slope Factor for 1,1-DCE. Memo from Joan S. Dollarhide. 2/18/94.
- (3): EPA, 1992. Environmental Criteria and Assessment Office (ECAO). Carcinogenicity Characterization of TCE, PCE and Styrene. Memo from Joan S. Dollarhide to Dave Crawford. 5/18/92.
- (4): Converted from Unit Risk Factor (Chloroform unit risk = 2.3E-05 ug/m³; 1,2-DCA unit risk = 2.6E-5 ug/m³;) 1,1-DCE unit risk = 5E-5 ug/m³)
- (5): Calculation of a slope factor from unit risk may be inappropriate due to use of pharmacokinetic model (unit risk given as 4.7E-07 ug/m³)
- (6): Recommendation of 1988 USEPA Science Advisory Board, not adopted
- (7): EPA, 1993. Environmental Criteria and Assessment Office (ECAO). Risk Assessment Issue Paper for: Evaluation of Systemic Toxicity After Inhalation Exposure to 1,2-Dichloroethenes. Memo from Joan S. Dollarhide. 2/18/94.
- (8): Recommendation; not officially adopted
- NE: Not evaluated for carcinogenicity by the EPA
- NA: Not available; There is inadequate evidence to quantitatively evaluate the carcinogenicity of the compound by this route (EPA, 1994)

TABLE 6-7

**TOXICITY VALUES FOR CHEMICALS OF CONCERN
NON-CARCINOGENS**

Chemical	Chronic Oral RfD (mg/kg/day)	Critical Effect	Uncertainty	Ref.	Chronic Inhalation RfD (mg/kg/day)	Critical Effect	Uncertainty	Ref.
1,1-Dichloroethene	9.0E-03	hepatic lesions	1000	(1)	9.0E-03	-	-	(8)
1,1-Dichloroethane	1.0E-01	none observed	1000	(2)	1.0E-01	kidney	1000	(3)
Cis-1,2-Dichloroethene	1.0E-02	decreased hematocrit and hemoglobin	3000	(2)	not available	-	-	(1)
Trans-1,2-Dichloroethene	2.0E-02	increased serum alkaline phosphatase	1000	(1)	2.0E-02	-	-	(8)
1,2-Dichloroethane	NA	-	-	(1)	1.4E-03 (7)	gastrointestinal tract liver	3000	(5)
1,1,1-Trichloroethane	9.0E-02	hepatotoxicity	1000	(4)	2.9E-01 (7)	reduced body weight gain	1000	(6)
Trichloroethene	under review	-	-	(1)	under review	-	-	(1)
Tetrachloroethene	1.0E-02	hepatotoxicity; weight gain	1000	(1)	1.0E-02	-	-	(8)

(1): EPA, 1994, Integrated Risk Information System (IRIS). On-line database

(2): EPA 1993, Health Effects Assessment Summary Tables (HEAST). OERR 9200.6-3-3(93-1) July.

(3): From HEAST Alternate Methods Table: value derived from methodology not current with the inhalation method used by the work group.

(4): Value taken from 1992 HEAST table. Current value has been withdrawn.

(5): EPA, 1994. Environmental Criteria and Assessment Office (ECAO). Risk Assessment Issue Paper for: Derivation of a Provisional Inhalation RfC for 1,2-Dichloroethane. Memo from Joan S. Dollarhide. 9/16/93.

(6): EPA, 1993. Environmental Criteria and Assessment Office (ECAO). Risk Assessment Issue Paper for 1,1,1-Trichloroethane. Memo from Joan S. Dollarhide. 9/16/93.

(7): Calculated from RfC value (methylene chloride RfC = 3E+0 mg/m³; 1,1,1-trichloroethane RfC = 1E+0 mg/m³; 1,2-DCA RfC = 5.0E-03)

(8): Inhalation RfD based on oral RfD

NE: Not evaluated for carcinogenicity by the EPA

NA: Not available; There is inadequate evidence to quantitatively evaluate the carcinogenicity of the compound by this route (EPA, 1994)

RfDs are available for the oral and inhalation exposure route, and information on the critical effects is provided for the specific duration of the study. In this assessment, the use of chronic RfDs is appropriate for the evaluation of lifetime exposures. Oral RfDs are also employed in the evaluation of dermal exposures.

Reference concentrations (RfC), presented in HEAST, can be used to derive inhalation RfDs according to the following equation:

$$\text{Reference Dose (mg/kg/day)} = \text{Reference Concentration (mg/m}^3\text{)} \times 20 \text{ m}^3\text{/day} \times 1/70 \text{ kg}$$

Reference concentrations are used to derive inhalation reference doses for TCA and 1,2-DCA.

The status of RfDs and RfCs for the chemicals of concern is summarized below:

Available:

- Oral RfD for 1,1-DCE
- Oral RfD for 1,1-DCA
- Oral RfD for cis-1,2-DCE
- Oral RfD for trans-1,2-DCE
- Oral RfD for PCE

- Inhalation RfC for 1,2-DCA
- Inhalation RfC for TCA

Alternate values used:

- Oral RfD for TCA (IRIS value withdrawn; Value from 1992 HEAST tables was used in this HRA).
- Inhalation RfC for 1,1-DCA (Value derived from the Alternate Methods Table in HEAST (USEPA, 1992b). These values have been developed for specific sites and EPA cautions against their generalized use).

Not Available or Under Review:

- Oral RfD for 1,2-DCA
- Oral RfD and Inhalation RfC for TCE
- Inhalation RfC for 1,1-DCE
- Inhalation RfC for cis-1,2-DCE
- Inhalation RfC for trans-1,2-DCE
- Inhalation RfC for PCE

In cases where an RfD was provided for one exposure route, but not for the other, CDM evaluated the applicability of extrapolating the given value to apply to the other route on a chemical - by - chemical basis.

For 1,1-DCE, the critical effect observed from oral exposure is hepatic lesions. Hepatotoxicity has also been observed in humans, presumably following the inhalation route. Preliminary clinical findings on workers exposed to DCE for up to 6 years in a DCE polymerization plant in New Jersey revealed a high incidence of hepatotoxicity. Liver scans and measurements of liver

enzymes in 46 workers revealed marked dysfunction in 27 (59%) of the exposed workers. These data were presented briefly with little detail, and no follow-up study has been reported. Therefore, these findings must be considered only in a qualitative sense (ATSDR, 1989). The liver is a major target organ of DCE toxicity following both acute and longer-term inhalation in laboratory animals. Hepatotoxicity includes both biochemical changes and histological changes. These effects appear to follow a dose-response relationship that may be influenced by duration of exposure (ATSDR, 1989). Based on this information, the oral RfD for 1,1-DCE was also used to evaluate the inhalation route of exposure.

For cis-1,2-DCE, the critical effect observed from oral exposure is decreased hematocrit and hemoglobin. No studies were located regarding hematological effects of cis-1,2-DCE in any animal species. No studies were located regarding the systemic effects (respiratory, gastrointestinal, hematological, hepatic, or renal) of cis-1,2-DCE in any animal species (ATSDR, 1990). Based on this lack of evidence, the oral RfD for cis-1,2-DCE was not used to evaluate the inhalation route of exposure.

For trans-1,2-DCE, the critical effect observed from oral exposure is increased serum alkaline phosphatase. A reduction in the levels of serum albumin and urea nitrogen, and a decrease in serum alkaline phosphatase were observed in rats after an 8-hour exposure via inhalation to 1000 ppm trans-1,2-DCE. Based on the similarity in effects, the oral RfD for 1,2-trans-DCE was also used to evaluate the inhalation route of exposure.

For PCE, the critical effects from oral exposure are hepatotoxicity and weight gain. Intermediate duration studies with animals involving inhalation exposures to 9 ppm resulted in liver enlargement and vacuolization of hepatocytes in mice. Exposures to 37 ppm and higher concentrations induced more pronounced hepatic pathological alterations. Adverse effects on the liver were associated with continuous exposure in mice and intermittent exposure in guinea pigs, mice, and rats (ATSDR, 1990). Based on this evidence, the oral RfD for PCE was used to evaluate the inhalation route of exposure.

For 1,2-DCA, the critical effects observed from inhalation exposure are seen in the gastrointestinal tract and the liver. Gastrointestinal symptoms have been observed in humans prior to death following oral exposure to 1,2-DCA (ATSDR, 1989). No studies were located regarding gastrointestinal effects in animals following oral exposure to 1,2-DCA. The compound 1,2-DCA has been implicated as a hepatotoxin after acute oral poisoning of humans. Consequences include severe hepatocellular damage, liver cirrhosis, and necrosis (ATSDR, 1989). There is limited evidence of liver toxicity in animals following exposure to 1,2-DCA. Of four studies, two subchronic and two chronic, involving mice and rats, only one subchronic study demonstrated mild liver changes consisting of a 15% increase in fat accumulation and an increase in liver triglycerides (Alumot, 1976 as reported in ATSDR, 1989). Due to the limited evidence, the inhalation RfD was not used to evaluate oral exposure to 1,2-DCA.

6.5 EXPOSURE ASSESSMENT

This section discusses the potential and probable routes of exposure to the chemical compounds present in the groundwater. The exposure pathways considered for this risk assessment will be

described and the procedure for deriving exposure point concentrations for these chemicals will be presented.

6.5.1 Physical Setting

Although contamination exists in other media at the Southeast Rockford Groundwater Contamination Site, the only media to be considered here will be the residential well water. Other affected media, such as surface soil and indoor air, exist primarily near source areas and will be evaluated during the source investigation. Water samples from 24 wells at 23 different locations were collected. These are residential wells, and currently there are no restrictions, either physical or administrative, which would prevent exposure to the water. For the purpose of this risk assessment, each residence will be considered separately, and risks will be calculated separately for each household. Receptors will be considered to be residents of that household.

6.5.2 Potentially Exposed Populations: Current and Future

As discussed under the site history, the investigation of the groundwater contamination at the Southeast Rockford Groundwater Contamination Site began in 1981. Subsequent investigations identified residents whose private well supplies were contaminated above specific criteria; these residents have since been connected to city water, thus eliminating their exposure to the contaminants of concern.

The risk assessment looks at the potentially exposed residents (those still using private wells) under the "no action" alternative, i.e., in the absence of any connection to city water, or the provision of temporary measures such as faucet filters or bottled water. Well data from each location are viewed as a separate data set, and therefore each residence or location will be the subject of a separate set of risk calculations. We have considered exposure to water through dermal contact while showering, ingestion, and the inhalation of volatilized compounds in household air and during and after showering. While there was one commercial well (2955 11th Street), exposure and risks associated with commercial water use are typically less than those associated with residential water use. Therefore, evaluation of all wells under a residential scenario results in conservative estimates of risk.

6.5.3 Potential Exposure Pathways

An exposure pathway consists of four primary components: (1) a source and mechanism of release; (2) an environmental transport medium; (3) a point of potential contact (an exposure point); and (4) an exposure route at the exposure point. If all four components are present, the exposure pathway is considered complete. Each mechanism defines a unique way by which residents are potentially exposed to the site. The only exposure scenario we will be considering in this risk assessment is the potable and non-potable usage of residential wells, during which residents of those homes will come in contact with the water. The exposure routes which are likely include the ingestion of the water, dermal contact with the water through showering, inhalation of the volatilized chemicals in the household air, and inhalation of the volatilized chemicals during and immediately after a shower. Inhalation of indoor air contaminated via

direct migration of vapors from groundwater into a residence will not be considered, as the residential air data which would help quantitate this pathway is not being used in this assessment.

6.5.4 Exposure Point Concentrations

6.5.4.1 Current Exposures

Exposure Point Concentrations (EPCs) are calculated individually for each residence to represent current exposure conditions. The EPC calculations used to derive these values are presented in Appendix K. Tables 6-8 through 6-10 (note that the information for 1726 Pershing is also applicable to 1730 Pershing as they share the same well) present the current-use scenario EPCs. Because EPCs are based on recent data and do not incorporate estimated future concentrations, this assessment represents exposures assuming static conditions. EPCs are calculated for each route of exposure at each house using the data points obtained during 1993 sampling and, in the case of non-detects, supplemented by data collected in 1990. Compounds which were not detected in any of the wells are not incorporated into the assessment. The ten compounds detected in at least one well are presented in Table 6-2. Of these ten compounds, only those detected at a particular residence are assessed for that residence; non-detects are not included unless the compound had been detected during the 1990 IEPA/CDM sampling. In that event, the compound is included in the quantitative risk assessment. Most of these compounds were reported as estimated (qualified with a "J") because they had been detected below the contract required detection limit. In order to account for the uncertainty of using the estimated data, the following approach is employed for compounds detected in 1990, but not detected in 1993:

- If the compound had previously been detected in 1990 at greater than the CRDL, the exposure point concentration is one-half of its detection limit.
- If the compound had previously been detected in 1990 at greater than 0.5 ppb (greater than one-half of the detection limit), the exposure point concentration is one-half of its detection limit.
- If a compound had previously been detected at 0.1-0.5 ppb (data qualified as "J", detected at less than one-half of the detection limit), the exposure point concentration is the average of its previous detection concentration and one-half of the detection limit.

All concentrations detected in the current round of sampling are used as reported, without modification, with the exception of TCE. The TCE concentrations which were used were those reported by the data validator, rather than those further qualified by the remedial investigation data user. Because TCE was detected in the trip blanks, the data user qualified all TCE detects below 1 ppb (previously qualified as "J" the data validator) as "U". The approach chosen for the risk assessment however was to use the more conservative of the two values, so the values specified by the initial data validator were used.

As approved by USEPA and IEPA, dermal and inhalation exposures are evaluated using the models presented in Estimating Dermal and Inhalation Exposure to Volatile Chemicals in

TABLE 6-8

**EXPOSURE POINT CONCENTRATIONS FOR INGESTION AND DERMAL EXPOSURE
ROUTES**

Chemical	1,1-DCE	1,1-DCA	Cis- 1,2-DCE	Trans- 1,2-DCE	1,2-DCA	1,1,1-TCA	TCE	PCE
3115 7th Avenue	-	-	0.0003*	-	-	0.001	0.0006	0.0006
3237 8th Street	0.0003*	0.0002	-	-	-	0.002	0.001	0.004
3302 Kishwaukee	-	-	-	-	-	0.001	-	0.001
3310 Collins	0.0003*	0.0003*	-	-	-	0.001	0.0006	0.0003
3245 Collins	-	0.0003*	-	-	-	0.0007	0.0003	0.0003
3201 8th Street	-	-	-	-	-	0.0005*	-	-
3218 9th Street	-	0.0002	-	-	-	0.002	0.002	0.0003
3021 9th Street	-	0.0005	-	-	-	0.002	0.001	-
2131 Harrison (A)**	0.005	0.015	0.010	0.0002	0.0006	0.018	0.008	0.0009
2131 Harrison (B)**	0.004	0.013	0.009	-	0.0005	0.018	0.006	0.0007
3112 19th Street	-	-	-	-	-	0.0006	0.0006	0.0002
3110 18th Street	0.00035*	0.0003*	-	-	-	0.0007	0.0002	-
3118 17th Street	-	0.0001	-	-	-	0.001	0.0009	0.0002
3106 Marshall	0.0003*	0.0002	-	-	-	-	0.0002	-
3131 Sewell	-	-	-	-	-	-	-	-
3107 Grant Park	-	-	-	-	-	-	-	-
1713 Harrison	0.002	0.009	0.008	0.0003*	-	0.050	0.004	0.0008
3024 20th Street	-	-	-	-	-	0.0006	0.0006	0.0003
841 Roosevelt	0.00035*	0.0002	0.0003*	-	-	0.002	0.001	0.003
1726 Pershing	0.0006	0.001	0.002	-	-	0.005	0.002	0.0004
2955 11th Street	0.0003	0.0009	0.001	0.0003*	0.0003*	0.002	0.001	-
3126 Collins	-	-	-	-	-	0.002	0.001	0.0004
1735 Hamilton	0.0003*	0.0003*	-	-	-	0.0008	0.0006	-
3028 8th Street	-	0.0005	-	-	-	0.001	0.0005	-

Values given in mg/l

*: Denotes compound not detected in 1993, but detected in 1990; EPC derived according to Section 6.5.4.1

** : 2131 Harrison A and B service 37 trailers and 5 homes located at Barrett's Mobile Home Park

TABLE 6-9

**EXPOSURE POINT CONCENTRATIONS FOR INHALATION OF HOUSEHOLD AIR
EXPOSURE ROUTE**

Chemical	1,1-DCE	1,3-DCA	Cis- 1,2-DCE	Trans- 1,2-DCE	1,2-DCA	1,1,1-TCA	TCE	PCE
House								
3115 7th Avenue	-	-	0.0001*	-	-	0.0005	0.0003	0.0003
3237 8th Street	0.0001*	0.0001	-	-	-	0.001	0.0005	0.0019
3302 Kishwaukee	-	-	-	-	-	0.0005	-	0.0005
3310 Collins	0.0001*	0.0001*	-	-	-	0.0005	0.0003	0.0001
3245 Collins	-	0.0003*	-	-	-	0.0003	0.0001	0.0001
3201 8th Street	-	-	-	-	-	0.0002*	-	-
3218 9th Street	-	0.0001	-	-	-	0.001	0.001	0.0001
3021 9th Street	-	0.0002	-	-	-	0.0010	0.0005	-
2131 Harrison (A)**	0.0024	0.0072	0.0048	0.0001	0.0003	0.0086	0.0038	0.0004
2131 Harrison (B)**	0.0019	0.062	0.0043	-	0.0002	0.0086	0.0029	0.0003
3112 19th Street	-	-	-	-	-	0.0003	0.0003	0.0001
3110 18th Street	0.0002*	0.0001*	-	-	-	0.0003	0.0001	-
3118 17th Street	-	0.00005	-	-	-	0.0005	0.0004	0.0001
3106 Marshall	0.0001*	0.0001	-	-	-	-	0.0001	-
3131 Sewell	-	-	-	-	-	-	-	-
3107 Grant Park	-	-	-	-	-	-	-	-
1713 Harrison	0.0010	0.0043	0.0038	0.0001*	-	0.024	0.0019	0.0004
3024 20th Street	-	-	-	-	-	0.0003	0.0003	0.0001
841 Roosevelt	0.0002*	0.0001	0.0001*	-	-	0.001	0.0005	0.0014
1726 Pershing	0.0003	0.0005	0.001	-	-	0.0024	0.001	0.0002
2955 11th Street	0.0001	0.0004	0.0005	0.0001*	0.0001*	0.001	0.0005	-
3126 Collins	-	-	-	-	-	0.001	0.0005	0.0002
1735 Hamilton	0.0001*	0.0001*	-	-	-	0.0004	0.0003	-
3028 8th Street	-	0.0002	-	-	-	0.0005	0.0002	-

Values given in mg/l

*: Denotes compound not detected in 1993, but detected in 1990; EPC derived according to Section 6.5.4.1

**.: 2131 Harrison A and B service 37 trailers and 5 homes located at Barrett's Mobile Home Park

TABLE 6-10

EXPOSURE POINT CONCENTRATIONS FOR INHALATION OF SHOWER AIR ROUTE

Chemical	1,1-DCE		1,1-DCA		Cis-1,2-DCE		Trans-1,2-DCE		1,2-DCA	1,1,1-TCA		TCE			PCE	
Shower Period	During	After	During	After	During	After	During	After	During	After	During	After	During	After	During	After
House																
3115 7th Avenue	-	-	-	-	0.0022*	0.0043*	-	-	-	-	0.0072	0.014	0.0043	0.0086	0.0043	0.0086
3237 8th Street	0.0022*	0.0043*	0.0014	0.0029	-	-	-	-	-	-	0.014	0.029	0.0072	0.014	0.029	0.058
3302 Kishwaukee	-	-	-	-	-	-	-	-	-	-	0.0072	0.014	-	-	0.0072	0.014
3310 Collins	0.0022*	0.0043*	0.0022*	0.0043*	-	-	-	-	-	-	0.0072	0.014	0.0043	0.0086	0.0022	0.0043
3245 Collins	-	-	0.0022*	0.0043*	-	-	-	-	-	-	0.005	0.0101	0.0022	0.0043	0.0022	0.0043
3201 8th Street	-	-	-	-	-	-	-	-	-	-	0.0036*	0.0072*	-	-	-	-
3218 9th Street	-	-	0.0014	0.0029	-	-	-	-	-	-	0.014	0.029	0.014	0.029	0.0022	0.0043
3021 9th Street	-	-	0.0036	0.0072	-	-	-	-	-	-	0.014	0.029	0.0072	0.0144	-	-
2131 Harrison (A)**	0.036	0.072	0.108	0.216	0.072	0.144	0.0014	0.0029	0.0043	0.0086	0.130	0.259	0.058	0.115	0.0065	0.013
2131 Harrison (B)**	0.029	0.058	0.094	0.187	0.065	0.130	-	-	0.0036	0.0072	0.130	0.259	0.043	0.086	0.005	0.0101
3112 19th Street	-	-	-	-	-	-	-	-	-	-	0.0043	0.0086	0.0043	0.0086	0.0014	0.0029
3110 18th Street	0.0025*	0.005*	0.0022*	0.0043*	-	-	-	-	-	-	0.005	0.0101	0.0014	0.0029	-	-
3118 17th Street	-	-	0.0007	0.0014	-	-	-	-	-	-	0.0072	0.014	0.0065	0.013	0.0014	0.0029
3106 Marshall	0.0022*	0.0043*	0.0014	0.0029	-	-	-	-	-	-	-	-	0.0014	0.0029	-	-
3131 Sewell	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3107 Grant Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1713 Harrison	0.014	0.029	0.065	0.130	0.058	0.115	0.0022*	0.0043*	-	-	0.360	0.720	0.029	0.058	0.0058	0.012
3024 20th Street	-	-	-	-	-	-	-	-	-	-	0.0043	0.0086	0.0043	0.0086	0.0022	0.0043
841 Roosevelt	0.0025*	0.005*	0.0014	0.0029	0.0022*	0.0043*	-	-	-	-	0.014	0.029	0.0072	0.014	0.022	0.043
1726 Pershing	0.0043	0.0086	0.0072	0.014	0.014	0.029	-	-	-	-	0.036	0.072	0.014	0.029	0.0029	0.0058
2955 11th Street	0.0022	0.0043	0.0065	0.013	0.0072	0.014	0.0022*	0.0043*	0.0022*	0.0043*	0.014	0.029	0.0072	0.014	-	-
3126 Collins	-	-	-	-	-	-	-	-	-	-	0.014	0.029	0.0072	0.014	0.0029	0.0058
1735 Hamilton	0.0022*	0.0043*	0.0022*	0.0043*	-	-	-	-	-	-	0.0058	0.012	0.0043	0.0086	-	-
3028 8th Street	-	-	0.0036	0.0072	-	-	-	-	-	-	0.0072	0.014	0.0036	0.0072	-	-

Values given in mg/m3

*: Denotes compound not detected in 1993, but detected in 1990; EPC derived according to Section 6.5.4.1

**: 2131 Harrison A and B service 37 trailers and 5 homes located at Barrett's Mobile Home Park.

Domestic Water (Schaum, et. al., 1991). Ingestion exposures are evaluated using guidance presented in Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part A) Interim Final (EPA, 1989b). Except in the cases described above for the inhalation of compounds, the EPCs used are the actual concentration of the chemical in the well water. For dermal exposures, use of the actual concentration is consistent with guidance presented in Dermal Exposure Assessment: Principles and Applications (EPA, 1992a) and the Schaum model. For the household air and shower air inhalation scenarios, the equations and assumptions used in the equations are presented in Tables 6-11 and 6-12.

Andelman has demonstrated that exposures during and directly after a shower can be comparable to that from direct ingestion of the contaminated water (Andelman, 1990). In this assessment, shower and whole-house exposures are estimated with the use of one-compartment models. Calculation of the EPCs resulting from exposure to household air incorporates values for the water flow rate in a house, house volume, exchange rate of air in the house, a mixing coefficient, and the fraction of contaminated air that volatilizes. For most variables, a value in the middle of the range is chosen; for the fraction of contaminants that volatilize, the high end of the range recommended by EPA is chosen in order to assume the most conservative value encompassing all VOCs evaluated.

Calculation of the EPCs resulting from exposure to volatilized compounds during and after a shower incorporates variables for water flow rate in the shower, time of shower, bathroom volume, and fraction of compounds that volatilize.

6.5.4.2 Future Exposures

Due to the low concentrations generated by the contaminant transport modeling system, specific quantitative estimates of future groundwater contaminant concentrations were not obtainable with reasonable degrees of certainty. Therefore, a range of future concentrations are generated, but are used as part of a qualitative, rather than quantitative, risk assessment. A more detailed description of the contaminant transport model is presented in section 5.0.

Two simulations were run to predict site conditions 70 years from the present. One simulation assumed a constant strength for the modelled source areas over the 70 year period. The second simulation assumed exponentially decaying sources. It should be noted that the combined concentrations of 1,1,1-TCA and 1,1-DCA were used in the contaminant transport simulations. The exponentially decaying source scenario was based on a rate roughly equivalent to the decline in source strength between the 1976 - 1985 source strengths and the 1986 - 1993 source strengths.

The 8a source was present in only the last period, so the decay rate was assumed to produce a half-life of ten years. Source Area 14 was assigned a strength of zero for all future simulations because it was remediated during the late 1980's.

Future transport simulations were made for Levels 5 and 6, which in the model represent the deeper and shallower portions of the unconsolidated aquifer, respectively (model stratigraphy is detailed in section 5). Level 6 represents that part of the unconsolidated aquifer near the water

TABLE 6-11

VARIABLES USED TO EVALUATE EXPOSURE PATHWAYS
Model : Derivation of Chemical Concentrations in Household Air (CA)

Formula: $CA = (WHF * CW * f) / (HV * ER * MC)$

VARIABLE	DEFINITION/UNIT	SELECTED VARIABLE	REASON FOR SELECTION	REFERENCE
CA	Chemical Concentration in Household Air (mg/m ³)	Chemical-Specific. See Table 6-9 for presentation of exposure point concentrations.	Values derived from groundwater EPCs	Schaum, et al., 1991
WHF	Water Flow Rate in Whole House (liters/day)	720	Default value for a typical house as reported by USDHUD	Schaum, et al., 1991
CW	Chemical Concentration in Water (mg/L)	Chemical-Specific. See Table 6-8 for presentation of exposure point concentrations.	Consistent with RME approach.	EPA, 1989b
f	Fraction of Contaminated Air that Volatilizes (unitless)	0.9	A range of 0.5 to 0.9 (applicable for VOCs) is recommended by EPA. The high end of the range has been selected to cover for all VOCs evaluated. (e.g. TCE is 81.8% volatilized)	Schaum, et al., 1991
HV	House Volume (m ³)	180	Estimated typical house volume as recommended by EPA	Schaum, et al., 1991
ER	Exchange Rate (day ⁻¹)	15	Estimated value. A range of 13 - 60 air changes per day for newer houses is recommended by EPA.	Schaum, et al., 1991
MC	Mixing Coefficient (unitless)	0.5	Estimated value. A range of 0.3 to 0.7 is recommended by EPA.	Schaum, et al., 1991

References:

Schaum, et. al., 1991. Estimating Dermal and Inhalation Exposure to Volatile Chemicals in Domestic Water. USEPA Office of Research and Development. Washington, D.C. 1991.

USEPA. 1989b. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part A) Interim Final. EPA/540/1-89/002. Office of Emergency and Remedial Response. Washington D.C. December, 1989.

TABLE 6-12

VARIABLES USED TO EVALUATE EXPOSURE PATHWAYS
Model : Derivation of Chemical Concentrations in Shower (CA1) and After Shower Air (CA2)

Formulas:

$$CA1 = CA \text{ Max}/2$$

$$CA2 = CA \text{ Max}$$

$$CA \text{ Max} = (CW * f * Fw * t1) / Va$$

VARIABLE	DEFINITION/UNIT	SELECTED VARIABLE	REASON FOR SELECTION	REFERENCE
CA1	Air Concentration During Shower (mg/m ³)	Chemical-Specific. See Table 6-10 for presentation of exposure point concentrations.	Values derived from groundwater EPCs	Schaum, et al., 1991
CA2	Air Concentration After Shower (mg/m ³)	Chemical-Specific. See Table 6-10 for presentation of exposure point concentrations.	Values derived from groundwater EPCs	Schaum, et al., 1991
CW	Chemical Concentration in Water (mg/L)	Chemical-Specific. See Table 6-8 for presentation of exposure point concentrations.	Consistent with RME approach.	EPA, 1989b
f	Fraction of Contaminated Air that Volatilizes (unitless)	0.9	A range of 0.5 to 0.9 (applicable for VOCs) is recommended by EPA. The high end of the range has been selected to cover for all VOCs evaluated. (e.g. TCE is 81.8% volatilized)	Schaum, et. al., 1991
FW	Water Flow Rate (liters/hour)	800	Estimated value. A range of 600 to 1,800 l/hr was reported by U.S. DHUD.	USDHUD, 1984
t1	Time of Shower (hours)	0.2	90th percentile value reported in James and Knuiman, 1987.	Schaum, et. al., 1991
Va	Bathroom Volume (m ³)	10	Estimated value. A range of 6 -16 m ³ is recommended by EPA.	Schaum, et. al., 1991

References:

Schaum, et. al., 1991. Estimating Dermal and Inhalation Exposure to Volatile Chemicals in Domestic Water. USEPA Office of Research and Development. Washington, D.C. 1991.

USDHUD. 1984. Residential Water Conservation Projects. Contract H-5230. March, 1984.

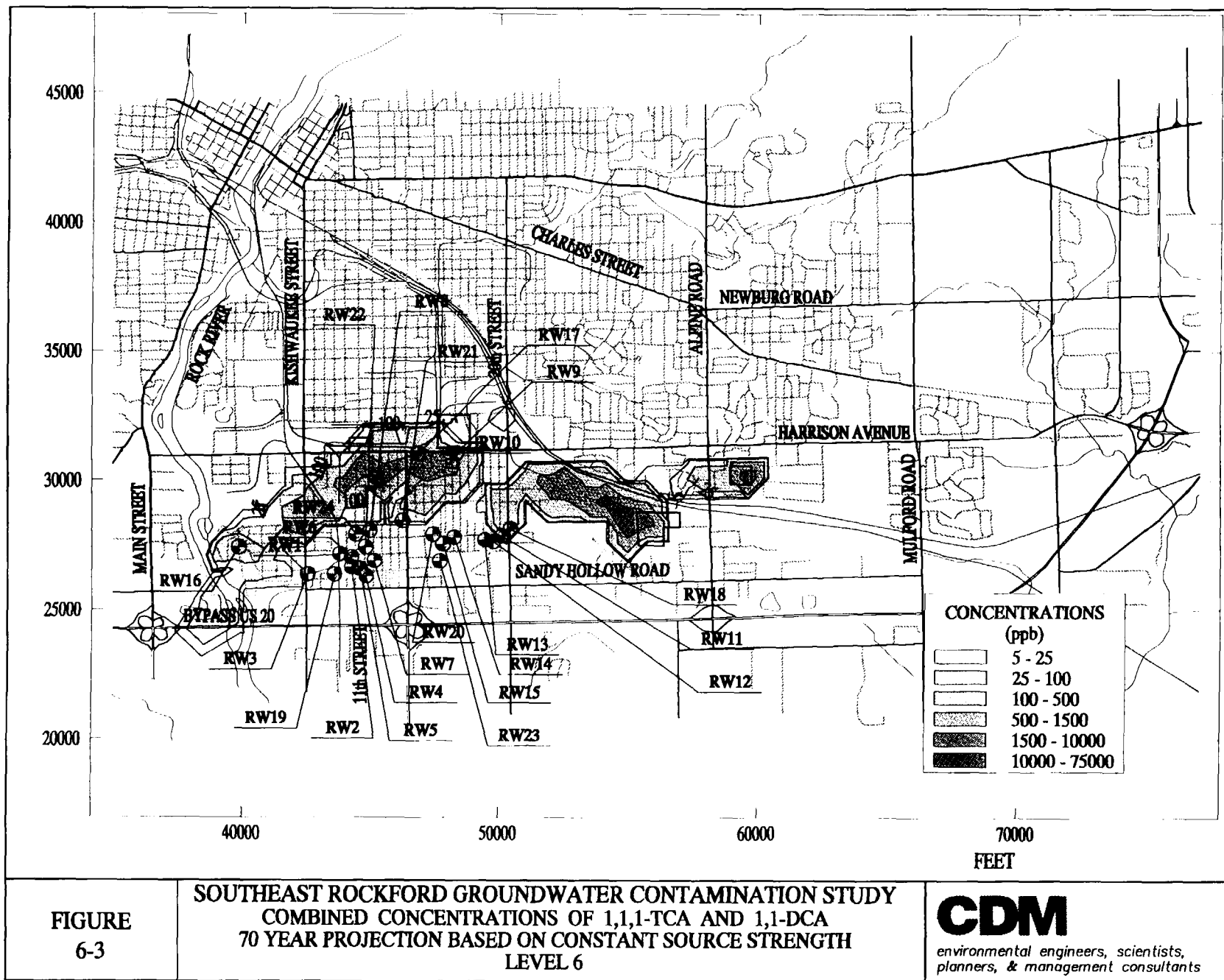
USEPA. 1989b. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part A) Interim Final. EPA/540/1-89/002. Office of Emergency and Remedial Response. Washington D.C. December, 1989.

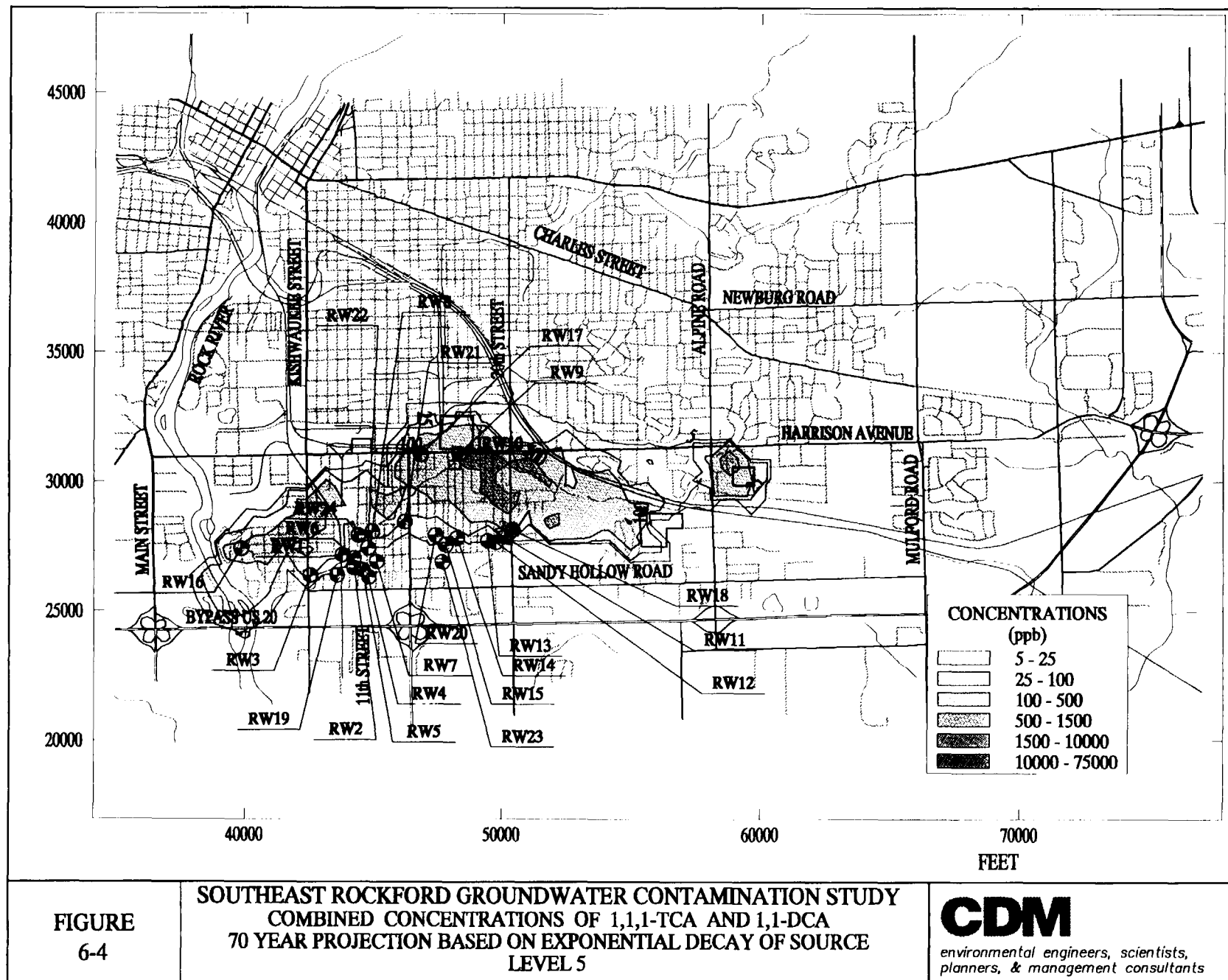
table. Level 5 generally represents the base of the unconsolidated aquifer and the top of the underlying Galena-Platteville Group (the dolomite aquifer); in those parts of the study area where the Galena-Platteville has been eroded, Level 5 represents the deep portions of the unconsolidated aquifer. Both Level 5 and 6 encompass portions of the unconsolidated aquifer and while available information indicates that residential wells in the study area are screened at shallow depth in the unconsolidated aquifer (Level 6), typically less than 80 feet based on information gathered from local residents, the level 5 simulation provides useful information on conditions in the lower portions of the aquifer. This suggests that the simulations for Level 6 are more representative of future contaminant concentrations at residential wells.

The 70-year projection based on a constant source strength is shown in Figures 6-2 and 6-3 for Levels 5 and 6 respectively. For all figures presenting 70-year projections, source areas are illustrated as red boxes within the plume. Level 5 is not expected to represent the situation for the majority of the residential wells because these wells are screened above this level. The simulation for Level 5 indicated that over half of wells would be located inside of future plume boundaries (Figure 6-2). Wells potentially located within the 5 to 25 ppb plume boundaries include those located at 3237 8th Street (RW 2), 3201 8th Street (RW 6), 3110 18th Street (RW 12), 3118 17th Street (RW 13), 3106 Marshall (RW 14), 841 Roosevelt (RW 19), 1726 Pershing (RW 20), 2955 11th Street (RW 21), and 3126 Collins (RW 22). Wells potentially located within the 25 to 100 ppb plume boundaries include those located at 3302 Kishwaukee (RW 3), 3021 8th Street (RW 8), 3112 19th Street (RW 11) and 3028 8th Street (RW 24). Wells potentially located within the 100 to 500 ppb plume boundaries include those located at 3115 7th Avenue (RW 1), 3107 Grant Park (RW 16), 1713 Harrison (RW 17) and 3024 20th Street (RW 18). Wells potentially located within the 500 to 1500 ppb plume boundaries include the two located at 2131 Harrison (RW 9 and RW 10). Wells located outside of projected plume boundaries include those at 3310 Collins (RW 4), 3245 Collins (RW 5), 3218 9th Street (RW 7), 3131 Sewell (RW 15) and 1735 Hamilton (RW 23).

However, assuming residential wells screened in Level 6, (Figure 6-3) a more likely scenario, only 7 wells are located within future plume boundaries; RW 11 and 21 are located within the 25-100 ppb plume, RW 9, RW 10, RW 16 and RW 18 are located within the 100 to 500 ppb plume, and RW 17 is located within the 500-1500 plume.

The 70-year projection based on exponential decay of source contamination yields a similar result. For Level 5 (see Figure 6-4), the only difference is RW 2 and RW 19 are now located outside of plume boundaries, and RW 1 is now located in the 5 to 25 ppb plume (instead of in the 100-500 ppb plume). For Level 6 (see Figure 6-5), the only change from the constant source scenario is that RW 9, RW 10, RW 17, and RW 18 are located in the 25-100 ppb plume (rather than the higher concentration plume). In general, the extent of high concentration contamination at both levels is lessened if an exponentially decaying source is assumed. All four simulations indicate that the plume will extend across the Rock River. Due to the limitations and uncertainty associated with projecting the calibrated model 70 years into the future, this should be considered as a possibility and not as an absolute certainty. An extensive discussion of the modeling simulations is presented in Section 5.0.





6.5.5 Chemical Intakes

The assumptions used to derive the chronic daily dose for all routes are presented in Tables 6-13 through 6-17. These exposure assumptions are derived from guidance documents including Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual:

Supplemental Guidance, "Standard Default Exposure Factors" (EPA, 1991) and Exposure Factors Handbook (EPA, 1989).

Maxwell et. al. (1991) reviewed literature concerning exposure to volatile organic chemicals in an attempt to determine the relative contributions of ingestion versus dermal and inhalation exposure to dose, and to try to compare different models for estimating dose. After running various models with the same concentration value for chloroform, the authors concluded that the contributions to total chemical dose from inhalation and dermal exposure routes may be as large as, or larger, than the contribution from the ingestion route.

Early models, such as Andelman's (1985) were simple, using a single compartment model, assuming total volatilization of the organic compounds and steady-state air concentrations, assuming a continuous infusion of chemical, and employing a mixing factor. McKone (1987) proposed a more complex model which incorporated factors for additional compartments, a variable infusion of contaminants, variable transfer efficiencies (relative to radon), time-dependent air concentrations, and a relative absorption factor of 0.5 (or 1.0 when calculating an upper bound estimate) for inhalation relative to ingestion. The upper bound estimate calculated from this model was slightly less than the lifetime estimate derived from Andelman's model.

The model estimates were compared to the results of a study performed by Jo et. al. (1990 a & b) in which the authors directly measured chloroform in the breath of people who had taken showers. The chloroform concentrations in breath were related linearly to the concentrations in the tap water used. The authors assumed a relative absorption factor of 0.77. Extrapolating the results to calculate a lifetime dose, the values were 2.5 times less than McKone's assumptions. In another phase of the study, participants wore rubber suits while showering in order to determine the dermally absorbed dose. When compared to regular showering results, chloroform levels in the breath dropped by about one-half, suggesting that the dermal exposure pathway contributes approximately the same as the inhalation pathway to the overall dose.

Maxwell's summary of the models found that the ratio of the lifetime inhalation dose to the lifetime ingestion dose may be in the range of 0.6 to 1.5, but possibly as high as 5.7. The ratio of the lifetime dermal dose to the lifetime ingestion dose is about 0.3 for showers and 1.8 for baths. The risk attributable to each pathway will vary depending on the specific toxicity factor used to determine risk. It should be noted however that in this paper, chloroform was the only chemical considered. At the Southeast Rockford study area, there is a mixture of chemicals, for which different results may be obtained.

The model used in this risk assessment (Schaum, 1991) is a one-compartment model, which averages inhalation time for the shower pathway in two segments: time spent in the shower, and

TABLE 6-13

VARIABLES USED TO EVALUATE EXPOSURE PATHWAYS

Model : Ingestion of Chemicals in Potable Groundwater

Formula: $CDI (mg/kg/day) = (CW * IR * EF * ED) / (BW * AT)$

VARIABLE	DEFINITION/UNIT	SELECTED VARIABLE	REASON FOR SELECTION	REFERENCE
CW	Chemical Concentration in Water (mg/L)	Chemical-Specific. See Table 6-8 for presentation of exposure point concentrations.	Consistent with RME approach.	EPA, 1989b
IR	Ingestion Rate (L/day)	2	Recommended by EPA. Value representative of ingestion rate for adults, (90th percentile)	EPA, 1991a
EF	Exposure Frequency (days/year)	350	Consistent with RME approach. Residents assumed to vacation/take time off 15 days out of the year.	EPA, 1991a
ED	Exposure Duration (years)	30	Consistent with RME approach. National upper-bound time (90th percentile) at one residence.	EPA, 1991a
BW	Body Weight (kg)	70	Recommended by EPA. (50th percentile)	EPA, 1991a
AT	Averaging Time (days)			
	- Carcinogens; 70 years * 365 days/year	25,550	Consistent with EPA approach	EPA, 1989b
	- Non-Carcinogens; ED (years) * 365 (days/year)	10,950	Consistent with EPA Approach	EPA, 1989b

References:

USEPA. 1989b. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part A) Interim Final. EPA/540/1-89/002. Office of Emergency and Remedial Response. Washington D.C. December, 1989.

USEPA. 1991a. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual. Supplemental Guidance. "Standard Default Exposure Factors". Interim Final. Office of Emergency and Remedial Response. Washington, D.C. March 25, 1991.

TABLE 6-14

VARIABLES USED TO EVALUATE EXPOSURE PATHWAYS
Model :Dermal Contact with Chemicals of Groundwater Origin (Nonsteady State)

Formula: $AD \text{ (mg/kg/day)} = (2 * CW * CF * PC * [\text{Square root } ((6 * T * ET) / \pi)]) * (SA * EF * ED) / (BW * AT)$

VARIABLE	DEFINITION/UNIT	SELECTED VARIABLE	REASON FOR SELECTION	REFERENCE
CW	Chemical Concentration in Water (mg/L)	Chemical-Specific. See Table 6-8 for presentation of exposure point concentrations.	Consistent with RME approach	EPA, 1989b
CF	Volumetric Conversion Factor for Water (l/cm ³)	1 l / 1000 cm ³		EPA, 1989b
PC	Dermal Permeability Constant (cm/hr)	Chemical Specific. See Table 6-15 for PC values.	Estimated value, recommended by EPA.	EPA, 1992a
T	Lag Time (hours)	Chemical Specific. See Table 6-15 for T values.		EPA, 1992a
ET	Exposure Time (hours/day)	0.2	Estimated value of 0.2 hours/day is equivalent to a 7-minute shower period. A range of 0.08 to 0.3 hours was reported by U.S. DHUD.	USDHUD, 1984; Schaum, et. al., 1991
SA	Skin surface area available for contact (cm ²)	19,400	50th percentile total body surface area for adult males	EPA, 1989a
EF	Exposure Frequency (days/year)	350	Consistent with RME approach.	EPA, 1991a
ED	Exposure Duration (years)	30	Consistent with RME approach. National upper-bound time (90th percentile) at one residence.	EPA, 1991a
BW	Body Weight (kg)	70	Recommended by EPA. (50th percentile)	EPA, 1991a
AT	Averaging Time (days) - Carcinogens; 70 years * 365 days/year	25,550	Consistent with EPA approach	EPA, 1989b
		10,950	Consistent with EPA Approach	EPA, 1989b

References:

- Schaum, et. al., 1991. Estimating Dermal and Inhalation Exposure to Volatile Chemicals in Domestic Water. USEPA Office of Research and Development. Washington, D.C. 1991.
- USDHUD. 1984. Residential Water Conservation Projects. Contract H-5230. March, 1984.
- USEPA. 1989a. Exposure Factors Handbook. EPA 600/8-89-043. Office of Health and Environmental Assessment. Washington, D.C. July, 1989.
- USEPA. 1989b. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part A) Interim Final. EPA/540/1-89/002. Office of Emergency and Remedial Response. Washington D.C. December, 1989.
- USEPA. 1991a. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual. Supplemental Guidance. "Standard Default Exposure Factors". Interim Final. Office of Emergency and Remedial Response. Washington, D.C. March 25, 1991.
- USEPA. 1992b. Dermal Exposure Assessment: Principles and Applications. EPA/600/8-91/011B. Office of Research and Development. Washington D.C. January, 1992.

TABLE 6-15
VARIABLES USED FOR DERMAL CONTACT MODEL:
Kp, T, t*, AND B FOR CHEMICALS OF CONCERN

Chemical	CAS No.	Measured Kp (cm/hr)	Estimated Kp (PC) (cm/hr)	T (hr)	t* (hr)	B
Methylene Chloride	75092		4.5E-03	2.9E-01	6.9E-01	1.8E-03
1,1-Dichloroethene	75354		1.6E-02	3.4E-01	8.2E-01	1.3E-02
1,1-Dichloroethane	75343		8.9E-03	3.5E-01	8.4E-01	6.2E-03
cis-1,2-Dichloroethene *	-	-	-	-	-	-
trans-1,2-Dichloroethene	540590		1.0E-02	3.4E-01	8.2E-01	7.2E-03
Chloroform	67663	1.3E-01	8.9E-03	4.7E-01	1.1E+00	9.3E-03
1,2-Dichloroethane	107062		5.3E-03	3.5E-01	8.4E-01	3.0E-03
1,1,1-Trichloroethane	71556		1.7E-02	5.7E-01	1.4E+00	1.1E-02
Trichloroethene	79016	2.3E-01	1.6E-02	5.5E-01	1.3E+00	2.6E-02
Tetrachloroethene	127184	3.7E-01	4.8E-02	9.0E-01	4.3E+00	2.5E-01

Notes:

Kp (cm/hr): Permeability coefficient for human exposure to contaminants in water

T (hr): Lag time

t* (hr): Time it takes to reach steady-state

B (unitless): Relative contribution of the permeability coefficients of the chemical in the stratum corneum and the viable epidermis.

***:** Values not provided for cis-1,2-dichloroethene; used values provided for trans-1,2-dichloroethene

Source: EPA, 1992. Dermal Exposure Assessment: Principles and Applications. EPA/600/8-91/011B.

TABLE 6-16

VARIABLES USED TO EVALUATE EXPOSURE PATHWAYS
Model : Inhalation of Airborne Chemicals of Groundwater Origin in Household Air

Formula: $CDI (mg/kg/day) = (CA * IR * ER * EF * ED) / (BW * AT)$

VARIABLE	DEFINITION/UNIT	SELECTED VARIABLE	REASON FOR SELECTION	REFERENCE
CA	Chemical Concentration in Household Air (mg/m ³)	Chemical-Specific. See Table 6-9 for presentation of exposure point concentrations.	Values derived from groundwater EPCs	Schaum, et al., 1991
IR	Inhalation Rate (m ³ /hour)	0.6	Recommended by EPA. Activity-specific inhalation rates were combined with time-use/activity level data to derive a daily indoor inhalation rate of 15 m ³ /day.	EPA, 1991a
ER	Exposure Rate (hours/day)	16		Schaum, et. al., 1991
EF	Exposure Frequency (days/year)	350	Consistent with RME approach.	EPA, 1991a
ED	Exposure Duration (years)	30	Consistent with RME approach. National upper-bound time (90th percentile) at one residence.	EPA, 1991a
BW	Body Weight (kg)	70	Recommended by EPA. (50th percentile)	EPA, 1991a
AT	Averaging Time (days)			
	- Carcinogens; 70 years * 365 days/year	25,550	Consistent with EPA approach	EPA, 1989b
	- Non-Carcinogens; ED (years) * 365 (days/year)	10,950	Consistent with EPA Approach	EPA, 1989b

References:

Schaum, et. al., 1991. Estimating Dermal and Inhalation Exposure to Volatile Chemicals in Domestic Water. USEPA Office of Research and Development. Washington, D.C. 1991.

USEPA. 1989b. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part A) Interim Final. EPA/540/1-89/002. Office of Emergency and Remedial Response. Washington D.C. December, 1989.

USEPA. 1991a. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual. Supplemental Guidance. "Standard Default Exposure Factors". Interim Final. Office of Emergency and Remedial Response. Washington, D.C. March 25, 1991.

TABLE 6-17

VARIABLES USED TO EVALUATE EXPOSURE PATHWAYS
Model : Inhalation of Airborne Chemicals of Groundwater Origin in Shower Air

Formula: $CDI (mg/kg/day) = [(CA1 * IR * SP) + (CA2 * IR * ASP)] * (EF * ED) / (BW * AT)$

VARIABLE	DEFINITION/UNIT	SELECTED VARIABLE	REASON FOR SELECTION	REFERENCE
CA1	Air Concentration During Shower (mg/m ³)	Chemical-Specific. See Table 6-10 for presentation of exposure point concentrations.	Values derived from groundwater EPCs	Schaum, et al., 1991
CA2	Air Concentration After Shower (mg/m ³)	Chemical-Specific. See 6-10 for presentation of exposure point concentrations.	Values derived from groundwater EPCs	Schaum, et al., 1991
IR	Inhalation Rate (m ³ /hour)	0.6	Recommended by EPA. Specific estimate for shower activity	EPA, 1989a
SP	Exposure Time During Shower (Shower Period) (hours/day)	0.2	90th percentile value reported in James and Knuiman, 1987.	Schaum, et al., 1991
ASP	Exposure Time After Shower (After Shower Period) (hours/day)	0.2	Estimated value of 0.2 hours/day is equivalent to a 12-minute after shower period. A range of 0.08 to 0.3 hours was reported by U.S. DHUD.	USDHUD, 1984
EF	Exposure Frequency (days/year)	350	Consistent with RME approach.	EPA, 1991a
ED	Exposure Duration (years)	30	Consistent with RME approach. National upper-bound time (90th percentile) at one residence.	EPA, 1991a
BW	Body Weight (kg)	70	Recommended by EPA. (50th percentile)	EPA, 1991a
AT	Averaging Time (days)			
	- Carcinogens; 70 years * 365 days/year	25,550	Consistent with EPA approach	EPA, 1989b
	- Non-Carcinogens; ED (years) * 365 (days/year)	10,950	Consistent with EPA Approach	EPA, 1989b

References:

- Schaum, et. al., 1991. Estimating Dermal and Inhalation Exposure to Volatile Chemicals in Domestic Water. USEPA Office of Research and Development. Washington, D.C. 1991.
- USDHUD. 1984. Residential Water Conservation Projects. Contract H-5230. March, 1984.
- USEPA. 1989a. Exposure Factors Handbook. EPA 600/8-89-043. Office of Health and Environmental Assessment. Washington, D.C. July, 1989.
- USEPA. 1989b. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part A) Interim Final. EPA/540/1-89/002. Office o
- USEPA. 1991a. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual. Supplemental Guidance. "Standard Default Exposure Factors". Interim Final. Office of Emergency and Remedial Response. Washington, D.C. March 25, 1991.

time spent in bathroom after the shower. This model assumes volatilization at a constant rate, and instant mixing. It assumes that the contaminant will reach a maximum concentration by the end of the shower and remain at that level for the post-shower periods. It assumes zero concentration at time zero (that no residual vapor is left over from a previous shower).

The authors of this model state that the ratio of the inhalation dose to the ingestion dose is dependent on the air exchange rate and mixing coefficients. In a house with a higher air exchange rate, the ratio of the inhalation dose to the ingestion dose will be relatively low (below 1), even for highly volatile compounds. For a "tighter" house, with lower air exchange rates, the ratio of the inhalation dose to the ingested dose will tend to be greater than one, and will increase to 4 for highly volatile compounds.

At the Southeast Rockford study area, we calculated the ratio of the dose for particular chemicals in the inhalation and dermal pathways versus the dose from the ingestion pathway. Calculations were performed for carcinogens at the homes on the 1E-05 risk range. Calculations were performed for noncarcinogens at homes with a hazard index of 5E-02 or greater. Calculations were performed for the chemicals which contributed most to the risk. These calculations are shown on Table 6-18. The ratio of inhalation to ingestion is usually 3.5 - 3.7 for selected compounds (the ratio for 1,1-DCE at 1713 Harrison was lower than this range at 2.3; the ratio for cis-1,2-DCE at 2131 Harrison (A) was higher than this range at 4.1; all others fell within the range). We assumed an exchange rate of 15 air changes per day. The recommended range is 13-60 by EPA for newer houses, and for older houses the air change rate would be expected to be even higher, so 15 is a conservative figure. We also chose the high end of the suggested volatilization range, 0.9 for all chemicals. The EPA recommended range is 0.5 to 0.9.

The contribution of the different pathways to overall risk varies greatly, depending on the toxicity values assigned to each chemical. The ratio of risk attributable to inhalation exposure versus risk attributable to ingestion exposure varies from 0.1 for PCE (carcinogenic effects) to 3.6-3.7 for PCE (noncarcinogenic effects) and 1,1-DCE (noncarcinogenic effects).

The traditional equation used to estimate dermally absorbed dose was based on the assumption that a steady-state condition in the skin was attained (when the amount of chemical entering the skin is equal to the amount exiting the skin). This approach also assumes that if a chemical enters the skin, it will at some point all be available to the body, and none will be lost by other processes. However, showering is likely to be completed before the attainment of steady-state conditions, and organic chemicals in the skin with an affinity for lipids are assumed to leach into the body after showering is complete. Therefore, dermal exposures may be underestimated using the typical equation. The important factor is whether or not the unsteady-state period of the chemical flux (t^*) is shorter or longer than the period of contact (0.2 hours). This is related to the permeability coefficients of the chemical in different skin layers, and the partition coefficient of the chemical between the different skin layers, and between the skin layers and medium (K_p). These values are presented in Table 6-15. In the absence of values for cis-1,2-DCE, the values for trans-1,2-DCE were used. EPA recommends that estimated rather than experimental K_p values be used in the estimation of chemical intakes (USEPA, 1992a).

TABLE 6-18

RELATIVE DOSE CONTRIBUTIONS: DAILY INTAKE OF TCE, CARCINOGENIC EFFECTS

		Ratio				Ratio		
		Estimated Dose	Inh Ing	Derm Ing	Derm + Inh Ing	Hazard Index	Inh Ing	Derm Ing
2131 Harrison (A)	Ingestion	9.4E-05	3.6	0.1	3.8	1.0E-06	2.0	0.2
	Dermal	1.3E-05				1.5E-07		
	Inhalation	3.4E-04				2.0E-06		
2131 Harrison (B)	Ingestion	7.0E-05	3.6	0.1	3.7	7.7E-07	2.0	0.1
	Dermal	1.0E-05				1.1E-07		
	Inhalation	2.5E-04				1.5E-06		
1713 Harrison	Ingestion	4.7E-05	3.6	0.1	3.8	5.2E-07	2.0	0.1
	Dermal	6.7E-06				7.4E-08		
	Inhalation	1.7E-04				1.0E-06		
1726 Pershing	Ingestion	2.3E-05	3.7	0.1	3.8	2.6E-07	1.9	0.1
	Dermal	3.3E-06				3.7E-08		
	Inhalation	8.4E-05				5.0E-07		

TABLE 6-18 (continued)

RELATIVE DOSE CONTRIBUTIONS: DAILY INTAKE OF 1,1-DCE, NONCARCINOGENIC EFFECTS

		Ratio				Ratio		
		Estimated Dose	<u>Inh</u> <u>Ing</u>	<u>Derm</u> <u>Ing</u>	<u>Derm + Inh</u> <u>Ing</u>	Hazard Index	<u>Inh</u> <u>Ing</u>	<u>Derm</u> <u>Ing</u>
2131 Harrison (A)	Ingestion	1.4E-04	3.6	0.1	3.7	1.5E-02	3.7	0.1
	Dermal	1.5E-05				1.7E-03		
	Inhalation	5.0E-04				5.5E-02		
2131 Harrison (B)	Ingestion	1.1E-04	3.6	0.1	3.7	1.2E-02	3.7	0.1
	Dermal	1.2E-05				1.4E-03		
	Inhalation	3.9E-04				4.4E-02		
1713 Harrison	Ingestion	5.5E-05	3.6	0.1	3.8	6.1E-03	3.6	0.1
	Dermal	6.1E-06				6.8E-04		
	Inhalation	2.0E-04				2.2E-02		
841 Roosevelt	Ingestion	9.6E-06	3.5	0.1	3.7	1.1E-03	3.5	0.1
	Dermal	1.1E-06				1.2E-04		
	Inhalation	3.4E-05				3.9E-03		
3237 8th Street	Ingestion	8.2E-06	3.7	0.1	3.8	9.1E-04	3.6	0.1
	Dermal	9.2E-07				1.0E-04		
	Inhalation	3.0E-05				3.3E-03		

TABLE 6-18 (continued)

RELATIVE DOSE CONTRIBUTIONS: DAILY INTAKE OF PCE, CARCINOGENIC EFFECTS

		Ratio				Ratio		
		Estimated Dose	<u>Inh</u> <u>Ing</u>	<u>Derm</u> <u>Ing</u>	<u>Derm + Inh</u> <u>Ing</u>	Hazard Index	<u>Inh</u> <u>Ing</u>	<u>Derm</u> <u>Ing</u>
2131 Harrison (A)	Ingestion	1.1E-05	3.5	0.5	4.0	5.5E-07	0.1	0.5
	Dermal	5.8E-06				3.0E-07		
	Inhalation	3.8E-05				7.6E-08		
2131 Harrison (B)	Ingestion	8.2E-06	3.7	0.5	4.2	4.3E-07	0.1	0.5
	Dermal	4.5E-06				2.3E-07		
	Inhalation	3.0E-05				5.9E-08		
1713 Harrison	Ingestion	9.4E-06	3.6	0.5	4.2	4.9E-07	0.1	0.6
	Dermal	5.1E-06				2.7E-07		
	Inhalation	3.4E-05				6.7E-08		
1726 Pershing	Ingestion	4.7E-06	3.6	0.6	4.2	2.4E-07	0.1	0.5
	Dermal	2.6E-06				1.3E-07		
	Inhalation	1.7E-05				3.4E-08		

TABLE 6-18 (continued)

RELATIVE DOSE CONTRIBUTIONS: DAILY INTAKE OF 1,1-DCE, CARCINOGENIC EFFECTS

		Ratio				Ratio		
		Estimated Dose	<u>Inh</u> <u>Ing</u>	<u>Derm</u> <u>Ing</u>	<u>Derm + Inh</u> <u>Ing</u>	Hazard Index	<u>Inh</u> <u>Ing</u>	<u>Derm</u> <u>Ing</u>
2131 Harrison (A)	Ingestion	5.9E-05	3.7	0.1	3.8	3.5E-05	1.1	0.1
	Dermal	6.6E-06				3.9E-06		
	Inhalation	2.2E-04				3.7E-05		
2131 Harrison (B)	Ingestion	4.7E-05	3.6	0.1	3.8	2.8E-05	1.1	0.1
	Dermal	5.3E-06				3.2E-06		
	Inhalation	1.7E-04				3.0E-05		
1713 Harrison	Ingestion	2.3E-05	2.3	0.1	2.5	1.4E-05	1.1	0.1
	Dermal	2.6E-06				1.6E-06		
	Inhalation	5.4E-05				1.5E-05		
1726 Pershing	Ingestion	7.0E-06	3.6	0.1	3.7	4.2E-06	1.1	0.1
	Dermal	7.9E-07				4.7E-07		
	Inhalation	2.5E-05				4.4E-06		

TABLE 6-18 (continued)

RELATIVE DOSE CONTRIBUTIONS: DAILY INTAKE OF TCA, NONCARCINOGENIC EFFECTS

		Estimated Dose	Ratio			Hazard Index	Ratio	
			Inh Ing	Derm Ing	Derm + Inh Ing		Inh Ing	Derm Ing
2131 Harrison (A)	Ingestion	4.9E-04	3.6	0.2	3.7	5.5E-03	1.1	0.2
	Dermal	7.6E-05				8.4E-04		
	Inhalation	1.7E-03				6.1E-03		
2131 Harrison (B)	Ingestion	4.9E-04	3.6	0.2	3.7	5.5E-03	1.1	0.2
	Dermal	7.6E-05				8.4E-04		
	Inhalation	1.7E-03				6.1E-03		
1713 Harrison	Ingestion	1.4E-03	3.6	0.2	3.7	1.5E-02	1.1	0.2
	Dermal	2.1E-04				2.3E-03		
	Inhalation	5.0E-03				1.7E-02		
841 Roosevelt	Ingestion	5.5E-05	3.7	0.2	3.8	6.1E-04	1.1	0.2
	Dermal	8.4E-06				9.4E-05		
	Inhalation	2.0E-04				6.8E-04		
3237 8th Street	Ingestion	5.5E-05	3.7	0.2	3.8	6.1E-04	1.1	0.2
	Dermal	8.4E-06				9.4E-05		
	Inhalation	2.0E-04				6.8E-04		

TABLE 6-18 (continued)

RELATIVE DOSE CONTRIBUTIONS: DAILY INTAKE OF PCE, NONCARCINOGENIC EFFECTS

		Estimated Dose	Ratio			Hazard Index	Ratio	
			<u>Inh</u> <u>Ing</u>	<u>Derm</u> <u>Ing</u>	<u>Derm + Inh</u> <u>Ing</u>		<u>Inh</u> <u>Ing</u>	<u>Derm</u> <u>Ing</u>
2131 Harrison (A)	Ingestion	2.5E-05	3.6	0.5	4.1	2.5E-03	3.6	0.6
	Dermal	1.3E-05				1.5E-03		
	Inhalation	8.9E-05				8.9E-03		
2131 Harrison (B)	Ingestion	1.9E-05	3.6	0.5	4.2	1.9E-03	3.6	0.5
	Dermal	1.0E-05				1.0E-03		
	Inhalation	6.9E-05				6.9E-03		
1713 Harrison	Ingestion	2.2E-05	3.5	0.5	4.1	2.2E-03	3.5	0.5
	Dermal	1.2E-05				1.2E-03		
	Inhalation	7.8E-05				7.8E-03		
841 Roosevelt	Ingestion	8.2E-05	3.7	0.5	4.2	8.2E-03	3.7	0.5
	Dermal	4.5E-05				4.5E-03		
	Inhalation	3.0E-04				3.0E-02		
3237 8th Street	Ingestion	1.1E-04	3.5	0.5	4.1	1.1E-02	3.5	0.5
	Dermal	6.0E-05				6.0E-03		
	Inhalation	3.9E-04				3.9E-02		

Under the model used in this assessment, and assuming that the exposure period does not exceed the unsteady-state period, dermal dose is expected to exceed ingested dose when the K_p value of the chemical (related to the chemical's speed of permeability) is greater than 0.1 cm/hr. Most compounds have K_p s below this level, and therefore dermal exposure is not expected to be a great contributor. Additionally, most of the experimental data from which K_p values have been derived has been done at room temperature - at the higher temperatures in the bath or shower, volatilization would be expected to increase, thereby decreasing the amount of chemical available for dermal absorption.

All chemicals evaluated in this risk assessment have estimated K_p s below 0.1 cm/hr, and therefore dermal exposure would not be expected to contribute strongly to dose in relation to the other pathways. The ratio of the dermal pathway's contribution to dose versus the ingestion pathway's contribution to dose is approximately 0.5 - 0.6 for PCE, and 0.0 - 0.2 for TCE, 1,1-DCE, cis-1,2-DCE, TCA, and 1,2-DCA (Table 6-18). As expected from the model, the dermal pathway did not contribute largely to dose.

The contribution of the different pathways to overall risk again varies, depending on the toxicity values assigned to each chemical, and the chemical specific parameters incorporated into the dermal exposure model. The ratio of risk attributable to dermal exposure versus risk attributable to ingestion exposure varies from 0.1 for TCE (carcinogenic effects) and 1,1-DCE (carcinogenic and noncarcinogenic effects) to 0.5 for PCE (carcinogenic and noncarcinogenic effects). The ratio of the resultant risks from dermal versus ingestion exposure is identical to the ratio dermal versus ingestion dose because the same toxicity factor was used for dermal and ingestion risk calculations.

Overall, using the Schaum model, the ratio of combined dermal and inhalation dose to the ingestion dose was in the range of 3.6 - 4.2 (with an outlier of 1,1-DCE at 1713 Harrison which was 2.5). This compares with the findings of Jo et. al. (1990 b), who determined that the chloroform dose from a shower (combining dermal and inhalation exposures from the event) ranged from 0.7 to 9 times the dose received from ingestion. The ratio is primarily influenced from the high contributions of the inhalation pathway, which in the Schaum model is due to the assumption of low ventilation and a high volatilization rate in the house.

Tables showing the calculations of a chronic daily intake for each route of exposure at each house are provided in Appendix L.

6.6 RISK CHARACTERIZATION

The potential cancer and non-cancer risks resulting from exposure to contaminated residential well water are quantified and discussed in this section. The exposure point concentrations derived in Section 6.5, and the toxicity values obtained in Section 6.4, are used to quantify the risks.

6.6.1 Carcinogens

Carcinogenic risks are calculated using oral and inhalation slope factors. A slope factor is an upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. It can be used to estimate the upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen. (EPA, 1991a). Intake is assumed to be over a 30 year period to approximate the national upperbound time at one residence. The carcinogenic risks estimated for each individual chemical are summed with the risks generated for the other chemicals present to estimate the total carcinogenic risk per exposure route. The totals from each route are then summed to obtain an overall cancer risk in each residence.

There is a background cancer risk which is attributable to such variables as lifestyle, diet, environment, and genetic predispositions. The risks determined in this assessment represent the increase in risk over background attributable to the site. A risk of $1.00\text{E-}06$ indicates that an individual in the household would have an additional 1 in 1,000,000 chance of developing cancer from exposure to the well water. This risk level is used to determine remediation goals when ARARs are not available, or not sufficiently protective because of the existence of multiple contaminants at the site (CFR, 1992).

6.6.2 Noncarcinogens

Noncarcinogenic effects are calculated using a chronic RfD. This is an estimate of a daily exposure level for humans that should not present an appreciable risk of health effects over the course of a lifetime (in contrast to a slope factor, which is an estimate of probability). The chronic daily intake value is divided by the chronic RfD to produce a hazard quotient for each chemical. Hazard quotients for all chemicals in a particular exposure route are summed to produce a hazard index. The totals for all the exposure routes are then summed to produce a hazard index for residential exposure.

If the hazard index is less than 1, it is considered that the exposure is unlikely to endanger human health. If the hazard index is greater than one, the total hazard index should be disaggregated according to toxic endpoints or target organs. If any of the disaggregated hazard indices are still greater than one, the applicability of the toxicity information to the exposure route of concern should be further evaluated along with the uncertainties inherent in the derivation of the toxicity values. In some cases, a hazard index greater than one may represent an unacceptable risk such that remedial action is appropriate.

6.6.3 Summary of Total Estimated Risks

Tables 6-19 and 6-20 present the estimated carcinogenic risks and noncarcinogenic hazard indices for household residents. The calculations are presented in Appendix L and are based on calculations presented in the USEPA Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part A) Interim Final (USEPA, 1989b) and in Estimating Dermal and Inhalation Exposure to Volatile Chemicals in Domestic Water (Schaum et. al, 1991).

TABLE 6-19

TOTAL OF CANCER RISKS PER HOUSEHOLD

Route of Exposure	Ingestion	Dermal	Inhalation of Household Air	Inhalation of Shower Air	Total Risk
House					
3115 7th Avenue	4.4E-07	2.1E-07	1.3E-07	7.3E-08	9E-07
3237 8th Street	4.7E-06	1.6E-06	1.8E-06	1.0E-06	9E-06
3302 Kishwaukee	6.1E-07	3.3E-07	5.4E-08	3.0E-08	1E-06
3310 Collins	2.4E-06	3.5E-07	1.5E-06	8.6E-07	5E-06
3245 Collins	2.2E-07	1.1E-07	6.5E-08	3.7E-08	4E-07
3201 8th Street	-	-	-	-	-
3218 9th Street	4.4E-07	1.4E-07	3.4E-07	1.9E-07	1E-06
3021 9th Street	1.3E-07	1.8E-08	1.6E-07	9.1E-08	4E-07
2131 Harrison (A)	3.7E-05	4.4E-06	2.6E-05	1.5E-05	8E-05
2131 Harrison (B)	3.0E-05	3.5E-06	2.1E-05	1.2E-05	7E-05
3112 19th Street	2.0E-07	7.8E-08	1.1E-07	6.1E-08	4E-07
3110 18th Street	2.5E-06	2.8E-07	1.7E-06	9.4E-07	5E-06
3118 17th Street	2.4E-07	8.3E-08	1.6E-07	8.8E-08	6E-07
3106 Marshall	2.1E-06	2.4E-07	1.5E-06	8.2E-07	5E-06
3131 Sewell	-	-	-	-	-
3107 Grant Park	-	-	-	-	-
1713 Harrison	1.5E-05	1.9E-06	1.0E-05	5.7E-06	3E-05
3024 20th Street	2.6E-07	1.1E-07	1.1E-07	6.4E-08	5E-07
841 Roosevelt	4.4E-06	1.3E-06	2.0E-06	1.1E-06	9E-06
1726 Pershing	4.7E-06	6.4E-07	3.2E-06	1.8E-06	1E-05
2955 11th Street	2.6E-06	2.7E-07	2.3E-06	1.3E-06	6E-06
3126 Collins	3.7E-07	1.5E-07	1.8E-07	1.0E-07	8E-07
1735 Hamilton	2.2E-06	2.5E-07	1.5E-06	8.6E-07	5E-06
3028 8th Street	6.5E-08	9.2E-09	8.1E-08	4.6E-08	2E-07

TABLE 6-20

TOTAL HAZARD INDEX PER HOUSEHOLD

Route of Exposure	Ingestion	Dermal	Inhalation of Household Air	Inhalation of Shower Air	Total Hazard Index
House					
3115 7th Avenue	3E-03	1E-03	4E-03	2E-03	1E-02
3237 8th Street	1E-02	6E-03	3E-02	2E-02	6E-02
3302 Kishwaukee	3E-03	2E-03	7E-03	4E-03	1E-02
3310 Collins	2E-03	6E-04	4E-03	2E-03	1E-02
3245 Collins	1E-03	5E-04	2E-03	1E-03	5E-03
3201 8th Street	2E-04	2E-05	1E-04	6E-05	3E-04
3218 9th Street	1E-03	5E-04	2E-03	1E-03	6E-03
3021 9th Street	7E-04	1E-04	8E-04	4E-04	2E-03
2131 Harrison (A)	5E-02	6E-03	8E-02	5E-02	2E-01
2131 Harrison (B)	5E-02	5E-03	7E-02	4E-02	2E-01
3112 19th Street	7E-04	3E-04	1E-03	8E-04	3E-03
3110 18th Street	1E-03	2E-04	3E-03	2E-03	6E-03
3118 17th Street	9E-04	3E-04	2E-03	9E-04	4E-03
3106 Marshall	1E-03	1E-04	2E-03	1E-03	5E-03
3131 Sewell	-	-	-	-	-
3107 Grant Park	-	-	-	-	-
1713 Harrison	5E-02	6E-03	4E-02	2E-02	1E-01
3024 20th Street	1E-03	5E-04	2E-03	1E-03	5E-03
841 Roosevelt	1E-02	5E-03	2E-02	1E-02	5E-02
1726 Pershing	1E-02	1E-03	8E-03	5E-03	2E-02
2955 11th Street	5E-03	4E-04	2E-02	1E-02	3E-02
3126 Collins	2E-03	7E-04	3E-03	2E-03	7E-03
1735 Hamilton	1E-03	1E-04	2E-03	1E-03	5E-03
3028 8th Street	4E-04	6E-05	5E-04	3E-04	1E-03

6.6.3.1 Noncarcinogens

The hazard indices for each household are all below 1, indicating that non-cancerous or toxic human health effects from exposure to the groundwater at these residences is unlikely. Wells in which the hazard index exceeded $1\text{E-}02$ are presented in Table 6-21.

There are three wells with a hazard index which exceeds $1\text{E-}01$ but is less than $3\text{E-}01$: the two wells located at 2131 Harrison, and the well at 1713 Harrison. With the models used in this risk assessment, the combined inhalation pathways (with household air predominating) contribute the most to dose and to the hazard index, although the route of ingestion is also a strong contributor to overall hazard index at 1713 Harrison, contributing more than either inhalation pathway alone. The compound cis-1,2-DCE (and TCA at 1713 Harrison) is the dominant chemical contributing to the overall hazard index for the ingestion and dermal exposure routes. The compound 1,1-DCE is the dominant chemical contributing to the hazard index for the two inhalation exposure routes.

Among the seven wells with a total hazard index equal to or greater than $1\text{E-}02$, but less than $1\text{E-}01$, the combined inhalation routes (with household air predominating) also tend to be the dominant exposure routes contributing to both dose and the overall hazard index. The dominant chemicals contributing to the hazard index include cis-1,2-DCE and PCE (for oral and dermal exposure routes), and PCE, cis-1,2-DCE, and 1,2-DCA (for the two inhalation routes).

Many of the chemicals that are examined in this assessment do not have current inhalation RfDs. Values are available only for 1,1-DCA, 1,2-DCA, and TCA. For 1,1-DCE, trans-1,2-DCE, and PCE, the oral RfDs were used to evaluate inhalation exposure. However, based on a lack of evidence, the oral RfD was not used to evaluate inhalation exposures for cis-1,2-DCE. Similarly, the inhalation RfD was not used to evaluate oral exposures for 1,2-DCA, and there was neither an oral RfD nor an inhalation RfD available for TCE. The inability to quantitatively evaluate all chemicals may lead to an underestimation of risks at the homes where these chemicals were present.

6.6.3.2 Carcinogens

USEPA has established a general $1.0\text{E-}04$ to $1.0\text{E-}06$ risk range as the target range within which the Agency attempts to manage risks. A risk level of $1.0\text{E-}04$ is the point below which action is generally not warranted, however the Agency may decide to attain the $1.0\text{E-}06$ risk level after a decision has been made to take action. (USEPA, 1991d) Thirteen of the twenty four wells sampled have a total carcinogenic risk within the risk range defined by the EPA. These homes are presented in Table 6-22.

Nine homes have a total carcinogenic risk ranging from $1\text{E-}06$ to $9\text{E-}06$. In increasing risk, these wells are 3302 Kishwaukee, 3218 9th Street, 3106 Marshall, 1735 Hamilton, 3310 Collins, 3110 18th Street, 2955 11th Street, 841 Roosevelt, and 3237 8th Street. Again, with the models used, the pathway which is the primary contributor to dose is the combined inhalation pathways, followed by ingestion and dermal contact. Ingestion is the dominant pathway contributing to risk in each home. The inhalation pathways are the second largest contributor to risk, followed

TABLE 6-21

DOMINANT EXPOSURE ROUTES AND CHEMICALS FOR NONCANCER RISKS

Route of Exposure	Ingestion			Dermal			Household Air			Shower Air			Total
	Risk	% Contribution	Dominant Chemical	Risk	% Contribution	Dominant Chemical	Risk	% Contribution	Dominant Chemical	Risk	% Contribution	Dominant Chemical	Risk
House													
2131 Harrison (A)	5.5E-02	29%	Cis-1,2-DCE	6.1E-03	3%	Cis-1,2-DCE	8.2E-02	43%	1,1-DCE	4.6E-02	24%	1,1-DCE	2E-01
2131 Harrison (B)	4.8E-02	30%	Cis-1,2-DCE	5.2E-03	3%	Cis-1,2-DCE	6.7E-02	42%	1,1-DCE	3.8E-02	24%	1,1-DCE	2E-01
1713 Harrison	4.8E-02	43%	Cis-1,2-DCE	5.9E-03	5%	1,1,1-TCA	3.7E-02	33%	1,1-DCE	2.1E-02	18%	1,1-DCE	1E-01
3237 8th Street	1.3E-02	20%	PCE	6.2E-03	10%	PCE	2.8E-02	45%	PCE	1.6E-02	25%	PCE	6E-02
841 Roosevelt	1.1E-02	22%	PCE	4.8E-03	10%	PCE	2.2E-02	44%	PCE	1.2E-02	25%	PCE	5E-02
2955 11th Street	4.9E-03	15%	Cis-1,2-DCE	4.3E-04	1%	Cis-1,2-DCE	1.8E-02	54%	1,2-DCA	9.9E-03	30%	1,2-DCA	3E-02
1726 Pershing	1.0E-02	41%	Cis-1,2-DCE	1.4E-03	6%	PCE	8.5E-03	34%	1,1-DCE	4.8E-03	19%	1,1-DCE	2E-02
3302 Kishwaukee	3.0E-03	21%	PCE	1.5E-03	10%	PCE	6.5E-03	44%	PCE	3.7E-03	25%	PCE	1E-02
3115 7th Avenue	2.7E-03	27%	PCE	1.0E-03	10%	PCE	4.1E-03	41%	PCE	2.2E-03	22%	PCE	1E-02
3310 Collins	2.1E-03	22%	1,1-DCE	6.0E-04	6%	PCE	4.4E-03	46%	1,1-DCE	2.5E-03	26%	1,1-DCE	1E-02

TABLE 6-22

RESIDENCES WITHIN THE EPA TOTAL RISK RECOMMENDATION

Route of Exposure	Ingestion			Dermal			Household Air			Shower Air			Total Risk
	Risk	% Contribution	Dominant Chemical	Risk	% Contribution	Dominant Chemical	Risk	% Contribution	Dominant Chemical	Risk	% Contribution	Dominant Chemical	
Within EPA Risk Range:													
3302 Kishwaukee *	6.1E-07	59%	PCE	3.3E-07	32%	PCE	5.4E-08	5%	PCE	3.0E-08	3%	PCE	1E-06
3218 9th Street	4.4E-07	40%	TCE	1.4E-07	12%	PCE	3.4E-07	31%	TCE	1.9E-07	17%	TCE	1E-06
3106 Marshall	2.1E-06	46%	1,1-DCE **	2.4E-07	5%	1,1-DCE **	1.5E-06	31%	1,1-DCE **	8.2E-07	18%	1,1-DCE **	5E-06
1735 Hamilton	2.2E-06	46%	1,1-DCE **	2.5E-07	5%	1,1-DCE **	1.5E-06	32%	1,1-DCE **	8.6E-07	18%	1,1-DCE **	5E-06
3310 Collins	2.4E-06	46%	1,1-DCE **	3.5E-07	7%	1,1-DCE **	1.5E-06	30%	1,1-DCE **	8.6E-07	17%	1,1-DCE **	5E-06
3110 18th Street	2.5E-06	46%	1,1-DCE **	2.8E-07	5%	1,1-DCE **	1.7E-06	31%	1,1-DCE **	9.4E-07	17%	1,1-DCE **	5E-06
2955 11th Street	2.6E-06	40%	1,1-DCE	2.7E-07	4%	1,1-DCE	2.3E-06	36%	1,1-DCE	1.3E-06	20%	1,1-DCE	6E-06
841 Roosevelt	4.4E-06	50%	1,1-DCE **	1.3E-06	15%	PCE	2.0E-06	22%	1,1-DCE **	1.1E-06	13%	1,1-DCE **	9E-06
3237 8th Street	4.7E-06	52%	PCE	1.6E-06	18%	PCE	1.8E-06	20%	1,1-DCE **	1.0E-06	11%	1,1-DCE **	9E-06
1726 Pershing	4.7E-06	46%	1,1-DCE	6.4E-07	6%	1,1-DCE	3.2E-06	31%	1,1-DCE	1.8E-06	17%	1,1-DCE	1E-05
1713 Harrison	1.5E-05	46%	1,1-DCE	1.9E-06	6%	1,1-DCE	1.0E-05	31%	1,1-DCE	5.7E-06	17%	1,1-DCE	3E-05
2131 Harrison (B)	3.0E-05	45%	1,1-DCE	3.5E-06	5%	1,1-DCE	2.1E-05	32%	1,1-DCE	1.2E-05	18%	1,1-DCE	7E-05
2131 Harrison (A)	3.7E-05	45%	1,1-DCE	4.4E-06	5%	1,1-DCE	2.6E-05	32%	1,1-DCE	1.5E-05	18%	1,1-DCE	8E-05

* Only one compound evaluated for carcinogenicity

** 1,1-DCE was not detected in 1993 sample; concentration based on detection in 1990 sample

by dermal contact. At 3302 Kishwaukee and 3218 9th Street, homes with a total risk of $1\text{E-}06$, the dominant chemicals contributing to risk are PCE and TCE. PCE is the only chemical detected at 3302 Kishwaukee. The only two chemicals detected at 3218 9th Street are PCE and TCE; PCE is the dominant chemical contributing to risk for the dermal exposure pathway, but TCE is the dominant chemical contributing to risk for the other three routes of exposure. The only other homes where PCE similarly dominated an exposure route are at 841 Roosevelt, with a total risk of $9\text{E-}06$, where PCE is the dominant chemical contributing to risk in the dermal route, and 3237 8th Street, with a total risk of $9\text{E-}06$, where PCE is the dominant chemical contributing to risk in both the ingestion and dermal exposure routes. In all other cases, the dominant chemical contributing to risk in all exposure routes is 1,1-DCE. In six of the seven homes where 1,1-DCE plays a role in determining carcinogenic risk (2955 11th Street being the exception), 1,1-DCE had not been detected in the 1993 sampling event. The compound is included in the risk assessment based on its detection in that well during the 1990 sampling event. The compound 1,1-DCE is classified as a Level C carcinogen, indicating that it is a possible human carcinogen, which is a lesser weight of evidence ranking than level B2, the ranking of 1,2-DCA, and the possible ranking (although not yet adopted by EPA) of TCE and PCE.

Four wells have a total carcinogenic risk ranging from $1\text{E-}05$ to $8\text{E-}05$: 1726 Pershing, 1713 Harrison, and the two wells at 2131 Harrison. Ingestion is the dominant pathway contributing to risk in each home. The second largest contributor to risk is the inhalation of household air, followed by inhalation of shower air, and dermal contact. For each house the dominant chemical contributing to risk in all exposure routes is 1,1-DCE. In these homes however, 1,1-DCE had actually been detected in the 1993 sampling event.

The wells at 1713 Harrison and 2131 Harrison Street have the largest number of different compounds detected, and also often have the largest concentrations of these compounds. The well at 1726 Pershing has six of the COCs detected, four of them in concentrations equal to or greater than 1 ppb. The three wells located on Harrison also have the highest hazard indices for noncarcinogenic risks.

6.6.4 Comparison of Detected Concentrations with Applicable or Relevant and Appropriate Requirements

A comparison of the detected residential well contaminants with Applicable or Relevant and Appropriate Requirements (ARARs) is presented in Table 6-2. Detected chemicals are compared to the Safe Drinking Water Act MCLs promulgated in 40 CFR 141 and the Class I Illinois Groundwater Standards, March 17, 1994. These standards are similar to the MCLs as shown in Table 6-2. Only one MCL and Groundwater Standard are exceeded, in the two wells located at 2131 Harrison. The MCL and Illinois Groundwater Quality Standard for trichloroethene is 0.005 mg/l , but TCE was detected in the two wells at 0.008 and 0.006 mg/l . It should be noted however, that MCLs consider only the route of ingestion; risks from dermal contact with, or inhalation of water containing these chemicals were not incorporated into the decision to set these standards, therefore it may be incorrect to assume that these levels are protective when all routes of exposure are summed together (U.S. EPA, 1994). This is an important consideration for

this site because the largest contribution to overall dose is derived from the inhalation pathways, not the ingestion pathway.

6.6.5 Summary of Current Risks

Noncarcinogenic hazard indices are all less than 1, indicating that noncarcinogenic effects to human health would not be expected. However, the lack of RfDs for some of the chemicals may result in an underestimation of noncarcinogenic hazard indices at the homes where these chemicals were present.

A summary table of wells whose carcinogenic risks are within the EPA target risk range is presented as Table 6-22. For many of these wells the risk assessment is driven by the inclusion of 1,1-DCE in the risk assessment at homes where it was a non-detect in this round of sampling, but was detected in 1990. No wells exceed the upper range of this limit at $1\text{E-}04$.

Two wells exceed the MCL and Illinois Class I Groundwater Quality Standard for TCE. These wells are both located at the same address, 2131 Harrison and service 37 trailers and 5 homes. These wells, and the well located at 1713 Harrison, present the highest noncarcinogenic and carcinogenic risks in the assessment.

The residential wells selected for inclusion in the Phase II study were located outside of the main portion of the plume. Most of these wells are located south of the contaminant plume and south of Brooke Road; three wells are located along the northern margin of the plume on Harrison Avenue.

The three highest non-cancer hazard index estimates were in wells on the edge of plume on Harrison Avenue. The three highest cancer risk estimates were in the same Harrison Avenue wells. Hazard indices and risk estimates for all wells were below EPA hazard index limits and within the EPA acceptable risk range. In general, residential wells closest to the main contaminant plume exhibited higher concentrations of chemicals of concern and associated hazard index and risk estimates. Hazard index and risk estimates for wells beyond the margins of the plume did not necessarily exhibit a decreasing trend with distance from the plume. Except for the three wells on Harrison Avenue, all detected concentrations of all chemicals for all wells beyond the margins of the plume were less than $5\text{ }\mu\text{g/l}$. While the chemicals detected in wells beyond the margins of the plume were generally consistent with those detected within the plume, the detected concentrations were too low to be definitively associated with the main plume.

The following conclusions about the entire site can be deduced from the risk assessment conducted for the residential wells:

1. Chemical concentrations detected in the residential wells were lower than concentrations detected in the monitoring wells within the main plume area. Because estimates of hazard index and risk are directly proportional to chemical concentration, should the wells within the main plume be used for drinking and associated household water uses, hazard indices

and risks associated with these wells would be higher than those estimated in the risk assessment for the wells outside of the plume.

2. Chemical concentrations detected in residential wells as part of the operable unit investigation were generally higher than concentrations detected during the Phase II assessment; therefore, those wells would have higher associated hazard indices and risk estimates. It is important to note that several of the residential wells sampled during the OU which were found to exceed Maximum Contaminant Levels were south of the presently defined main plume. These wells, and abutting wells have been hooked up to public water.

6.6.6 Future Risks

Quantitative risks were not calculated for the future use scenario because the low concentrations estimated to be present caused a large degree of uncertainty and wide range of values resulting from the model. However, a qualitative assessment can be derived from looking at the wells affected. The wells along Harrison Avenue (1713 Harrison and two wells at 2131 Harrison) are affected under the current use scenario, and both simulations at both levels demonstrate that these wells will continue to be affected in the future, albeit to different degrees depending on the scenario and level. Current total VOC levels in these wells range from 52 to 74.3 ppb. Future total VOC levels would be expected to be higher than the value for just 1,1,1-TCA and 1,1-DCA combined. For the well at 1713 Harrison, predicted values under the constant source scenario for 1,1,1-TCA and 1,1-DCA combined range from 100 to 500 ppb at Level 5 to 500-1,500 ppb at Level 6. Under the decaying source scenario, the values range from the same as the constant source scenario for Level 5 to 25-100 ppb at Level 6. For the wells at 2131 Harrison, predicted values under the constant source scenario for 1,1,1-TCA and 1,1-DCA combined range from 500-1,500 ppb for Level 5 to 100-500 ppb for Level 6. Under the decaying source scenario, the values range from the same as the constant source scenario for Level 5 to 25-100 ppb for Level 6. Therefore, depending on the scenario and the level assumed, contaminant concentrations and subsequent risks could either increase or decrease.

In general, any home located within the 70-year projected plume boundaries could be expected to see an increase in risk due to predicted concentrations being higher than measured concentrations from the 1993 sampling. Some homes predicted to be within future plume boundaries but which are not currently exhibiting carcinogenic risk within the EPA's recommended range of $1E-04$ to $1E-06$ (including 3107 Grant Park, 3112 19th Street, 3118 17th Street, 3024 20th Street, 3021 8th Street, 3126 Collins, 3115 7th Street, 3021 9th Street and 3028 8th Street) and which currently do not exhibit any contaminants greater than 3 ppb could be expected to demonstrate an increase in risk. Other homes which are located within future plume boundaries, and currently exhibit risks within the EPA range (1726 Pershing, 2955 11th Street, 3110 18th Street, 3106 Marshall, 3302 Kishwaukee, 841 Roosevelt, 3237 8th Street, and the previously discussed wells on Harrison Street) may be expected to exhibit a higher degree of risk in the future, since the minimum concentration predicted by the plume boundary, 5 ppb, is often higher than the concentrations currently seen. Only 1726 Pershing, with a total VOC concentration of 11 ppb 841 Roosevelt with a total VOC concentration of 6.5 ppb, and 3237 8th

Street with a total VOC concentration of 7.5 ppb currently exceed the lower bound of the predicted values (although 2955 11th Street has a total VOC concentration of 5.2 ppb).

Other homes which currently exhibit carcinogenic risks in this range (3310 Collins, 1735 Hamilton, and 3218 9th Street) are not predicted to fall within the path of the plume. Exclusion from future plume boundaries however does not imply the absence of risk. Many of the homes which currently display carcinogenic risk within the EPA range do so when displaying total contaminant concentrations less than 2 ppb. Since future plume boundaries are only shown for concentrations of 5 ppb and greater, it is possible that many homes not currently affected could see contaminant concentrations increase to the 1 to 5 ppb range, and therefore may display carcinogenic risk. Also, total chemical concentrations are likely to be higher than the predicted plume totals of 1,1,1-TCA and 1,1-DCA.

6.7 Uncertainty In The Risk Assessment

The uncertainty inherent in the process of risk assessment cannot be totally eliminated. The assumptions made tend to be conservative, resulting in an over-estimation of the actual risk from the site. This section will discuss the assumptions and procedures used in this risk assessment which could lead to over-estimation or under-estimation of cancer and non-cancer risks at the site.

6.7.1 Types of Uncertainty

The EPA Guidelines for Exposure Assessment, published in 1992, list three categories of uncertainty:

- Scenario uncertainty
- Parameter uncertainty; and,
- Model uncertainty

Scenario uncertainty refers to information which would be used to define the site-specific exposure and dose. This uncertainty can arise due to errors in site history and description, errors that arise in an assumption of homogeneity (either in populations or conditions), errors in professional judgement, or errors resulting from an incomplete analysis (i.e., not including every pathway or route). Parameter uncertainty refers to the assumptions and parameters used in concentration, dose, and risk calculations. Parameter uncertainty can arise from analytical errors in the data, errors arising from non-representative or incomplete data, errors arising due to temporal changes (changes in contaminant concentration or human activity due to variations in time, seasons, etc.), and assumptions made regarding exposure factors when specific information is unavailable. Model uncertainty originates from the models used to provide an estimate of exposure. Over-simplification of a situation, or errors in correlation between chemical properties may result.

Each stage of the risk assessment data evaluation, toxicity assessment, exposure assessment, and risk characterization has some degree of uncertainty. These areas of uncertainty are presented in

Table 6-23, along with an evaluation of the magnitude of their effect on the overall risk assessment. The sources of uncertainty are discussed in detail below.

6.7.2 Scenario Uncertainty

In this risk assessment, each well is considered the subject of an individual risk characterization except in the case of the 2131 Harrison wells, each well services only one residence. The wells at 2131 Harrison service 42 residences. Each well therefore has its own data set, and completeness of data is not an issue. The data collected apply only to residences where sample collection occurred and therefore, are very representative of exposures at those residences. The likelihood of exposure to residential well water at these residences is very high.

All compounds which were detected in the field samples by the laboratory are used in the risk assessment with the exception of methylene chloride and chloroform. Ingestion, dermal exposure, and the inhalation of volatilized compounds under two situations are the chosen routes of exposure. However, the selection of only one exposure pathway, exposure to residential groundwater, will introduce uncertainty to the risk assessment. Air and soil contamination, which could contribute to risk, are not included. Inhalation of indoor air impacted via direct migration of vapors from groundwater and/or soil into a residence has not been evaluated in the quantitative part of this assessment. Residential air data was evaluated qualitatively in Section 4. This may be especially significant in homes with basement living spaces or those situated over areas of high groundwater VOC concentrations. Therefore, total overall risk at the site may be underestimated since these other pathways are not quantified. Potential underestimation of risk would be expected to be largest at 2131 Harrison, immediately west of Area 4, where surface soil contamination was detected during the Phase II investigation. The majority of the homes south of Harrison are located in residential areas with little industrial activity. While surface soil contamination is less likely in such an area, the soil has not been sampled, so the presence of contaminated surface soil is unknown. Both soil and indoor air exposure will be evaluated as part of the source area investigations.

6.7.3 Parameter Uncertainty

Since each well was subject to an individual risk characterization, the actual sample data collected at that well is used. This eliminated the need to average the data, and possibly overestimate or underestimate the risk at each well. However, reliance on a single sample to estimate risk does present a moderate amount of uncertainty. Differences which would be seen with different sampling events, which could result from natural causes (seasonal variation) or introduced causes (due to sampling and analytical techniques) are not accounted for. Predicted concentrations for most homes currently within the plume are generally higher than exposure point concentrations based on the most recent data. In this regard, risk estimates based on the assumption of static conditions over a 30-year exposure duration appear to be underestimated for future conditions.

TABLE 6-23

QUALITATIVE EVALUATION OF THE IMPACT OF SOURCES OF UNCERTAINTY ON RISK RESULTS

Risk Assessment Component: Assumption (Type of Uncertainty)	Potential Magnitude for Over-estimation of Risk	Potential Magnitude for Under-estimation of Risk	Potential Magnitude for Over or Under Estimation of Risk
Data Evaluation			
Lack of comparability between data sets (parameter uncertainty)			Low
Use of only one sample point per household (parameter uncertainty)			Medium
Exclusion from risk assessment of non-detected chemicals in 1993 or 1990 (parameter uncertainty)		Low	
Inclusion of chemicals detected in previous rounds (parameter uncertainty)	Medium		
Inclusion of chemicals detected below contract required detection limit (parameter uncertainty)	Low		
Exclusion of chloroform and methylene chloride, detected in high concentrations in field blanks (parameter uncertainty)		Low	
Inclusion of TCE despite its presence in trip blank (parameter uncertainty)	Low		

TABLE 6-23 (continued)

QUALITATIVE EVALUATION OF THE IMPACT OF SOURCES OF UNCERTAINTY ON RISK RESULTS

Risk Assessment Component: Assumption (Type of Uncertainty)	Potential Magnitude for Over-estimation of Risk	Potential Magnitude for Under-estimation of Risk	Potential Magnitude for Over or Under Estimation of Risk
Exposure Assessment:			
Exclusion of soil and air exposure pathways (scenario uncertainty)		Medium (High for 2131 Harrison)	
Use of most current data to represent 30-year exposures (parameter uncertainty)		Medium	
Use of variable assumptions in exposure and intake calculations (parameter uncertainty)			Low
Assumptions of shower model: chronic exposure, constant volatilization, no ventilation (model uncertainty)	Medium		
Use of Kp Values (model uncertainty)			Low
Assumptions of dermal model: all chemical in skin is available to body (model uncertainty)	Medium		
Risk Characterization			
Unknown synergistic effects of chemical mixtures (parameter, modeling uncertainty)			Medium

TABLE 6-23 (continued)

QUALITATIVE EVALUATION OF THE IMPACT OF SOURCES OF UNCERTAINTY ON RISK RESULTS

Risk Assessment Component: Assumption (Type of Uncertainty)	Potential Magnitude for Over-estimation of Risk	Potential Magnitude for Under-estimation of Risk	Potential Magnitude for Over or Under Estimation of Risk
<p>Toxicity Assessment:</p> <p>Use of upper bound cancer slope factors to evaluate risks (parameter uncertainty)</p> <p>Use of RfDs which incorporate uncertainty factors (parameter uncertainty)</p> <p>Exclusion of compounds with no quantifiable toxicity value (parameter uncertainty)</p> <p>Use of withdrawn oral reference dose for 1,1,1-TCA (parameter uncertainty)</p> <p>Use of oral RfDs for compounds without inhalation RfDs (parameters uncertainty)</p> <p>Use of trans-1,2-DCE values for cis-1,2-DCE dermal exposure parameters (parameters uncertainty)</p> <p>Extrapolation of animal toxicity data to humans (parameter uncertainty)</p>	<p>Medium</p> <p>Medium</p>	<p>Medium</p>	<p>Medium</p> <p>Medium</p> <p>Medium</p> <p>Medium</p>

This risk assessment includes compounds which were detected above contract required detection limits as well as estimated ("J") values below contract required detection limits. The exclusion of the "non-detects" may result in an under-estimation of actual risks at the site. In an attempt to correct for this, compounds which were detected at a particular house during the 1990 sampling event, but not detected at that house in 1993, are included in the risk assessment for that house at the following concentrations:

- Compounds detected in 1990 above the contract required detection limit (with no "J" qualifier) are assessed at 1/2 of the detection limit.
- Compounds detected in 1990 at 0.1 to 0.5 ppb are assessed at a concentration which is the average of the concentration detected in 1990 and one-half of the detection limit.
- Compounds detected in 1990 at concentrations greater than 0.5 ppb are assessed at one-half of their detection limit.

With this approach we hope to assume a more conservative stance with the previously detected compounds, but not place more importance on them than on the compounds currently detected at low levels. Similarly, we chose the more conservative stance by using the TCE values as determined by the data validator (values under 1 ppb qualified as "J") rather than using the TCE values as determined by the remedial investigation data user (values under 1 ppb qualified as "U").

The use of qualified data could result in either an under-estimation or an over-estimation of risk. Since analytical methods are less accurate when detecting concentrations lower than the contract required detection limits because these values are outside of the calibration range, the actual value may be higher or lower than the reported value. Additionally, methylene chloride and chloroform were detected in the three field blanks at concentrations greater than five times the concentrations detected in the samples. The sample concentrations were treated as non-detects and not included in the risk assessment. The potential for under-estimation exists in the event that contamination was site-related. Trichloroethene was also detected in the trip blanks at higher concentrations than some sample concentrations. Because TCE was a known site-related contaminant, it has not been eliminated from the risk assessment.

The lack of comparability between data sets for a particular house (Table 6-3) cannot be fully explained. The degree of comparability varies greatly. This could be due to differences or errors in sampling techniques or laboratory analysis. Variations in concentration could also be due to temporal variations such as seasonal fluctuations in water table elevations. The 1989 sampling events took place in the fall and winter but the 1990 and 1993 sampling events both took place in the summer. The result could be either an over or under-estimation of risk.

Variables used in estimating exposure point concentrations are shown on Tables 6-11 and 6-12. Estimated values used in the derivation of chemical concentrations in household air or shower air include the water flow rate in the house or bathroom, house or bathroom volume, exchange rate, mixing coefficient, time of shower, and the fraction of contaminant that volatilizes. When available, EPA recommendations are chosen for the variables, such as water flow rate, house

volume, and mixing coefficient. For other values such as the exchange rate, and the fraction of volatilization, the more conservative estimate is chosen which would provide a maximum concentration and possible over-estimation of risk.

Variables values used in the estimation of chronic daily intakes are shown in Tables 6-13 through 6-17. Values for the ingestion rate of water, inhalation rate of air, exposure frequency, exposure duration, body weight, and averaging time are all chosen to be consistent with the EPA reasonable maximum exposure (RME) approach. Other variables, such as time spent during and after a shower, are estimated.

Another important source of uncertainty is the toxicity assessment. The derivation of the RfDs, RfCs, and slope factors used in risk assessment are based on the results of experimental data from toxicity studies. These toxicity values are then extrapolated, from animal species to human, from high experimental dose to lower actual concentration dose, or from one route of exposure to another route of exposure. Each extrapolation introduces the probability of error and uncertainty in the final risk number.

Slope factors are given a weight-of-evidence classification to qualify the certainty of a compound being classified as a carcinogen (Table 6-5). Compounds evaluated as carcinogens in this risk assessment are classified as either (1) probable human carcinogens (B2 classification) with sufficient evidence of carcinogenicity in animals and inadequate or lack of evidence in humans or (2) possible human carcinogens (C classification) with limited evidence of carcinogenicity in animals and inadequate or lack of evidence in humans. There are no compounds classified as "A", a definite human carcinogen. Therefore, there is a degree of uncertainty associated with the carcinogenicity classification of each compound. Most values are obtained from the EPA's Integrated Risk Information System (IRIS) database, which provides peer-reviewed data; slope factors for trichloroethylene and tetrachloroethene are obtained from the EPA's Environmental Criteria and Assessment Office (ECAO), which provides values that have not yet been approved for inclusion into the IRIS database. Since these two compounds are present in a majority of the samples, they add additional uncertainty to the risk figures for a number of the homes.

Additionally, there are a number of compounds for which slope factors were not provided. Trans-1,2-DCE has not yet been evaluated for carcinogenicity, and 1,1-DCA, although classified as a "C" level carcinogen, has no available slope factor. These compounds are not included in the quantitative risk assessment. Their omission could potentially drive the overall risk estimate down, and drive the proportional contributions to risk of the remaining compounds up.

RfDs and RfCs are assigned uncertainty factors to account for the necessary extrapolations from original experimental conditions. For most compounds the uncertainty factor was 1000, although for cis-1,2-DCE the factor was 3000, indicating greater uncertainty. Inhalation RfDs are not available, or cannot be derived, for a majority of the compounds. The oral RfD for the most prevalent compound in the data set, TCA has been withdrawn; in its place its former value is used, which is under question because of issues with species-to-species extrapolation. It is used in order to quantitatively evaluate TCA by all exposure routes, so that risk is not be underestimated by its omission. Therefore risk may be over or underestimated due to use of an inaccurate value. The inhalation RfC value for 1,1-DCA is from the HEAST Alternate Methods Table. These values are not recommended for general use. There is no oral or inhalation RfD

for TCE, and no inhalation RfD for PCE, the two other most commonly encountered compounds in the data set. In some instances, oral RfDs were used to evaluate toxicity for the inhalation pathway, when no RfC or RfD was available for that exposure route. The use of an oral RfD for the inhalation pathway may lead to either an under- or over-estimation of risk. Where evidence to suggest this substitution was lacking, the compound was not evaluated quantitatively, which could lead to an underestimation of risk in affected households.

A further consideration is the little known effect of chemical mixtures. Toxicological data is usually derived from studies involving exposure to one isolated compound. However, as is the case at this site, the households are subject to exposure to a number of compounds. The possible synergistic effects of the mixture are unknown and unquantified. It is possible that the chemicals together may offer a more-than-additive (synergistic) or less-than-additive (antagonistic) total risk, and that therefore the calculated risks are underestimated or overestimated.

6.7.4 Model Uncertainty

The models used to calculate exposure and intake are based on a series of parameter assumptions which may not always be applicable, as discussed above. The approach used to determine inhalation exposure during showering assumes chronic exposure, which does not occur during showering. The model however would present a worst-case scenario so the risks would be over-estimated. The model also assumes constant volatilization and no ventilation (such as an exhaust fan), assumptions which would also lead to an overestimation of risk.

The model used to calculate dermal exposure and absorption makes use of chemical specific values for Kp (dermal permeability) and lag time. Kp values are one of the more uncertain parameters used in exposure assessment due to experimental error, uncertainty in procedures, and extrapolation procedures used in their derivation. (EPA, 1992). Additionally, no values are provided for cis-1,2-DCE, so values for trans-1,2-DCE are substituted. The model, which is only applicable for volatile compounds, also assumes that all chemical which enters the skin will become available to body, and nothing will be lost to metabolism, evaporation, or other pathways. Therefore, this model may also lead to an over-estimation of risk.

The uncertainty inherent in the contaminant transport model used to predict future exposures at relatively low concentrations diminishes its use as a quantitative tool in this HRA. However, a brief discussion of the uncertainty inherent in its use as a qualitative tool is warranted. The primary source of uncertainty when using the model is how well the groundwater flow field is calibrated to accurately represent the movement of groundwater. Another limitation affecting the accuracy of the transport model is incomplete knowledge of source area histories, which leads to assumptions regarding when they started as source areas, how long they functioned in this capacity, and how strong they are. Assumptions were also made to estimate the decay rate.



Section Seven

Section 7

Conclusions and Recommendations

7.1 Conclusions

Geology

The geology of the study area generally comprises highly eroded bedrock overlain by unconsolidated glacial sediments of variable thickness. The buried bedrock surface represents preglacial valleys and uplands. The Rock Bedrock Valley, the precursor of the present-day Rock River, runs north-south through the study area. An east-west tributary valley to the Rock Bedrock valley runs through the study area.

Three bedrock units of Ordovician age are present at the bedrock surface in the study area: the Galena, Platteville, and Ancell Groups. The Ancell Group consists of the St. Peter Sandstone and the overlying Glenwood Formation.

The Galena and Platteville Groups are dolomite bedrock units characterized by porous or vuggy zones near the bedrock surface. The Glenwood is characterized by variable lithology consisting of dolomitic sandstone and an uppermost shale unit. This shale was observed in one of the two boreholes that penetrated the St. Peter Sandstone. The St. Peter Sandstone was observed to be a white quartz sandstone.

The unconsolidated sediments in the eastern portion of the study area are complexly interbedded glacial till, moraine and outwash deposits consisting of sands, silts, and clays with silts and clays representing approximately 30 percent of the unconsolidated sediments.

The unconsolidated sediments in the western portion of the study area are predominantly sand with some gravel and discontinuous silt and clay layers. Unconsolidated units in the study area are generally discontinuous and most likely abut the bedrock valley walls.

Hydrogeology

There are three aquifers of concern within the study area: the unconsolidated glacial sediments (unconsolidated aquifer), the Galena-Platteville (dolomite aquifer), and the St. Peter Sandstone (sandstone aquifer). Unconsolidated aquifer generally overlies the dolomite aquifer in the eastern half of the study area and overlies the sandstone aquifer in the western half.

The unconsolidated aquifer is hydraulically connected to the dolomite aquifer in the east and to the sandstone aquifer in the west.

Groundwater flow direction in the unconsolidated and dolomite aquifers is generally to the west. The flow pattern in the sandstone aquifer is influenced by municipal well pumping.

Vertical hydraulic gradients are present between the unconsolidated and bedrock aquifers and within the dolomite aquifer. Geographically, the wells with an upward gradient are generally in the center of the study area, bounded by Twentieth Street, Alpine Road, Harrison Avenue and Sandy Hollow Road.

Significant vertically downward hydraulic gradients were observed across the lower part of the Galena-Platteville Group and Glenwood Formation.

The mean horizontal hydraulic conductivities in the unconsolidated aquifer, as measured by slug tests, were approximately 4.0×10^{-5} ft/sec for both the eastern and western portion of the study area. The mean conductivity of the dolomite aquifer was slightly lower at 3.0×10^{-5} ft/sec. The mean conductivity of the sandstone aquifer was greater than that of either the dolomite or unconsolidated aquifers, at 1.1×10^{-4} ft/sec.

Borehole geophysical logging conducted by the U.S. Geological Survey identified horizontal flow pathways in the dolomite aquifer. Groundwater flow along these pathways is significantly greater than in the adjacent rock matrix.

Data Quality

Based on the data validation, the Phase II data set met the QC acceptance criteria of 95 percent as stated in the QAPP.

TCLP Results

The test pit samples that were analyzed for TCLP contained levels that exceed the TCLP standards for PCE and TCE. This indicates that materials from this area and areas of similar concentrations would require transport and disposal as a hazardous waste.

Air Sampling Results

Air samples collected upwind and downwind of the test pits during excavation did not exceed occupational exposure standards for the volatile organics analyzed.

All of the volatile organic compounds detected in residential homes are below health-based guidelines.

The concentrations of volatile organics detected in Area 4 residences are consistent with those compounds prevalent in the groundwater; however, for homes near Area 7, it is not possible to correlate the volatile organics with the groundwater contamination, because the concentrations in the air are close to the typical background concentrations.

Contaminants of Concern

VOCs are the primary groundwater contaminants in the contaminated shallow aquifers in the study area, including chlorinated VOCs, BETX compounds, and ketones. Other contaminants are

found only locally, and then primarily only in soils, including certain PAHs, pesticides, PCBs, heavy metals, and cyanide. Chlorinated VOCs are the most frequently detected and most abundant contaminants; in order of decreasing abundance, these contaminants are TCA, TCE, 1,2-DCE, 1,1-DCA, 1,1-DCE, and PCE.

Source Area Characterization

Areas 4, 7, 11, and 9/10 are likely to have affected downgradient groundwater quality within the primary area of concern, based on soil gas and subsurface soil sampling, and in the case of Area 7, test pit excavation and sampling.

Areas 12 and 13 have locally affected groundwater quality based on soil gas, subsurface soil and groundwater sampling, however the full extent of any groundwater plumes is not known.

Based on disposal information, the appearance of oily substances, as well as high contaminant concentrations at or near the water table greater than the solubilities in water of the respective compounds, it is suspected that non-aqueous phase liquids (NAPLs) are present in source areas 4, 7, 11, and 12. The Phase II investigation did not confirm the presence of or characterize NAPL contamination. The significance of identifying contaminant sources as NAPLs is that NAPLs will not mix appreciably with water; owing to the limited solubility and volatility of the constituent VOCs, NAPLs will tend to remain at or near their original location below the disposal site for an extended period of time. As a result, NAPLs pose a continuing contaminant source to groundwater through the slow dissolution of their constituent compounds into infiltrating rainwater and groundwater.

The presence of light, non-chlorinated compounds such as aromatics, alkanes, and ketones (including tentatively identified compounds or TICs) in the likely sources in Areas 4, 7, 11, and 12 appear to be responsible for a condition in which the overall specific gravities of each of these contaminant masses are less than or close to 1.0. The resultant nature and distribution of these contaminant masses appear to be taking on the characteristics of LNAPLs that may exist within the highly contaminated areas identified during the investigation in the shallow portions of the aquifer.

The distinction of the contaminant source materials as LNAPL with DNAPL compounds associated with it, is significant in terms of site characterization and remediation: LNAPLs tend to form relatively continuous, compact masses near the water table - such bodies are easier to define the limits of as well as to clean up; DNAPL occurrences, on the other hand, commonly feature hard-to-find narrow stringers and finger-like projections of contaminants that penetrate far into the saturated zone, and may also comprise pools at great depth resting on strata of lower permeability - such distributions are commonly very difficult to find and to clean up. Both LNAPL and DNAPL zones are suspected near source areas 4, 7, 11 and 12.

Each of the potential source areas containing areas of high contamination and suspected residual NAPL in the vadose zone differs somewhat in the composition of the contamination present, particularly in the proportion of the various chlorinated VOCs, the proportion of aromatic compounds, and the proportion of degradation daughter products.

The contamination in Area 4 consists primarily of TCA, a common solvent and DNAPL component, with no other TCL compounds being detected (detection limit for Area 4 soils was about 8% of the TCA concentration); TICs comprised mainly alkanes. The relative lack of aromatic compounds may be the reason that daughter products are present at fairly low concentrations (less than 10% that of TCA) in Area 4 subsurface soils and downgradient groundwater (see subsection 4.9.2). Available data suggests that the highly contaminated zone in Area 4 may be generated from a single source. This zone in Area 4 area has dimensions of roughly 50 by 75 feet, with a maximum thickness of at least eight feet. Residual NAPL may be present within this zone.

The contamination in Area 7 differs from that in Area 4 in that it is much more complex in composition: in addition to high concentrations of several chlorinated VOCs (TCA, PCE, TCE, and 1,2-DCE), which are DNAPL compounds, and high levels of the aromatics xylene, ethylbenzene, and toluene are present, which are LNAPL compounds; among the TICs, even higher concentrations were reported, with both aromatics and alkanes represented. The relatively high proportion of aromatic compounds in Area 7 may account for the high proportion of biodegradation daughter products in subsurface soils and downgradient groundwater. This may also account for the presence of the highly contaminated soils at or near the water table. The highly contaminated area in Area 7 appears to be a sinuous zone with dimensions of about 200 by 1,200 feet; the thickness in most of this zone is between five and 20 feet, but is locally 40 feet. This area is likely the result of disposal of many types of wastes over a period of time. It is suspected that zones of residual NAPL contamination are present in this area.

In Area 11, the contamination differs from that in the other likely source areas in that chlorinated VOCs are present at relatively low concentrations when compared to the concentration of aromatic compounds. These compounds were present at ppm levels likely masking the detection of any chlorinated compounds that could be present at ppb levels. LNAPL compounds such as xylene, toluene, and ethylbenzene are found to be the most abundant compounds on the TCL; similar or lower concentrations of total TICs are also present, including both alkanes and aromatics. There appear to be two separate areas of highly contaminated soil in Area 11, the larger having areal dimensions of at least 30 by 120 feet; the thickness of this larger area is generally five to 10 feet, and locally as great as 25 feet. This contamination is likely the result of spillage of varnish and paint removers from the facilities in that area. Based on the information obtained in Phase II, it is suspected that NAPL contamination is present at the water table.

Though Area 11 apparently did not cause notable increases in the total of chlorinated VOCs in downgradient groundwater, its high contribution of BETX compounds to the aquifer apparently created a reducing chemical environment that fostered the degradation of certain chlorinated VOCs, resulting in the formation of locally high concentrations of daughter products including vinyl chloride.

The contamination in Area 12 is somewhat similar to that in Area 7, based on the wide variety of contaminants present in subsurface soils. High concentrations (ppm-level) of chlorinated VOCs (PCE, TCE, and TCA), aromatics (xylene, ethylbenzene, and toluene), and ketones (2-butanone and acetone) are present; among TICs, aromatics, alkanes, ketones, and amides are present at

total concentrations about twice that of the total of chlorinated VOCs. The Area 12 contamination differs from that of Area 7 in the proportions of compounds: in Area 12 soils PCE and TCE are greater than TCA, and ketones are a major fraction of detected contaminants; the opposite holds in Area 7. The zone of high contamination in Area 12 has a thickness of about 15 feet and probable lateral dimensions of no more than 140 square feet. It is suspected that within this area, zones of residual NAPL contamination are present.

Where low-permeability units such as sandy silts and clayey silts are present at or near the water table, they have become infiltrated with NAPL compounds; some of the highest head-space and contaminant concentrations are present in the silty units. This process is fostered by the extended period of time available for infiltration (probably about 40 years in Area 7), and possibly by the chemical effects of the solvent contaminants. The primary significance of this pattern is for remediation, because cleanup of this type of contaminant mass in a silty unit may require considerably more time than cleanup in a sandy interval.

Contaminant Fate in Source Areas and in Groundwater

Contaminant volatilization has acted to deplete the source materials of portions of the more-volatile compounds. The end result is that through time, the contaminant source in Area 7 contains progressively higher proportions of less-volatile constituents such as PCE, xylene, and naphthalene.

The solubility of a contaminant in water is a key control on its migration in groundwater. In general, higher-solubility contaminants tend to have lower susceptibility to sorption, and thus tend to migrate relatively rapidly in groundwater. The role of solubility (and sorption) has been demonstrated in the study area, based on contaminant concentrations in groundwater compared to concentrations in both source materials and in soils away from the source areas.

Once VOCs enter subsurface soils, a major process affecting their fate is biodegradation through reductive dechlorination. This degradation process proceeds under anaerobic conditions, and results in the sequential loss of chlorine atoms; compounds containing one less chlorine atom are formed in each biodegradation step. The transformation of vinyl chloride to carbon dioxide is a biodegradation process, but this proceeds in an aerobic environment.

As noted above, reductive dechlorination requires an anaerobic environment to proceed. The existence of an anaerobic environment in the likely source areas is supported by the subsurface soil analytical results: in Areas 7, 11, and 12, there are high concentrations of xylene in the highly contaminated intervals, along with other non-chlorinated aromatic (e.g., toluene) compounds. The significance of these results is that these compounds are readily degradable; their degradation consumes oxygen, which creates an anaerobic environment.

Biodegradation probably accounts for the existence of a major fraction of 1,1-DCA, 1,2-DCE, chloroethane, vinyl chloride, and some of the TCE present in groundwater and subsurface soils. Biodegradation is also suggested in the study area because of the correlation of certain of the daughter compounds with their likely parent compounds (e.g., 1,1-DCA follows TCA; 1,2-DCE follows TCE).

Downgradient from the end of the aromatic compound plumes, oxygen is no longer consumed by the degradation of these compounds. The resulting abundance of free oxygen changes the chemical environment from reducing to oxidizing, which means that reductive dechlorination of the chlorinated VOCs ceases. This pattern is illustrated in both the Area 7 and Area 11 plumes: downgradient from the disappearance of BTEX compounds in these plumes, no discernible changes in the proportion of parent to daughter compounds is seen (the exception is vinyl chloride, which is susceptible to degradation under oxidizing conditions - it thus parallels the BTEX compounds). It should be noted that because of the relatively smaller mobility of the aromatic compounds compared with chlorinated VOCs, anaerobic conditions in the aquifer are present for only limited distances away from aromatic-rich source areas.

Contaminant Plume Characterization

The chlorinated organic compounds TCA, TCE, PCE, 1,1-DCA, 1,1-DCE, and 1,2-DCE all form relatively extensive groundwater contaminant plumes in the study area. The trends in the distribution of these compounds in the groundwater is generally similar and, in most cases the plumes are spatially separate. Within the scope of the Phase II study, eleven distinct plumes were defined in the study area. The Area 4, Area 7, Area 8 and Area 9/10 plumes are relatively well-defined, while others are either based on only several wells, or plume boundaries are not well known (the other identified plumes are the Area 11, Area 13, Area 15, Area 16, Area 17, Area 18, and Area 19 plumes).

The identified plumes that likely impacted the area requiring alternate water supply are the Area 7 plume, and possibly the Area 9/10 and Area 4 plumes.

The Area 7 plume is the largest and best characterized contaminant plume in the study area; it extends from an area just west of Alpine Road, south of Harrison Avenue to a location just west of Eleventh Street south of Harrison Avenue. This plume begins in Area 7 and gradually migrates from the shallow portion of the aquifer system to depths of about 200 feet between MW103 and MW101. Downgradient (west) of MW101, this plume affected residential wells across a wide area, necessitating hookups of these residences to municipal water supplies. Downgradient of MW101, the Area 7 plume probably stays at about the same elevation.

The Area 7 plume shows coherent behavior regarding relative contaminant abundances. In general, across the plume the ratios of the major contaminants to TCA (the most abundant contaminant) fall within a limited range. These ratios appear to reflect the composition of the Area 7 contaminant source as defined to date, based on comparison of groundwater results to subsurface soil and soil gas sampling results; this is also supported by the fact that the contaminant ratios in other plumes tend to fall within different ranges (e.g., lower TCE/TCA ratios in Areas 4 and 8 plumes than in the Area 7 plume; higher TCE/TCA ratios in Area 16 plume). In regard to the Area 7 and Area 8 plumes, a review of the nature and distribution of the TCE, PCE, and DCE plumes being generated from Area 7 appears to be spatially separate from the Area 8 plume which exists upgradient and northeast of the Area 7 plume. The Area 7 plume also behaves coherently in that contaminant concentrations decline steadily in the downgradient direction (west-northwest). Taken together, these patterns support the idea that

the Area 7 plume originates from a single, large contaminant source near the east end of Balsam Lane. It should be noted that the extent of this source area has not been defined, particularly to the north where recent evidence of waste piles was reported.

The Area 8 contaminant plume has the second-highest concentrations of chlorinated VOCs in the study area. This plume appears to originate from an area just east of Alpine Road, south of Harrison Avenue and extend to an area almost midway between Alpine Road and Twentieth Street, north of the Area 7 plume. The Area 8 plume has its own distinctive fingerprint, with a low ratio of TCE to TCA, and relatively high proportions of 1,1-DCE compared to other plumes. These patterns have held from Phase I (when sampling in the Area 8 plume was more extensive) to Phase II, and across the entire plume, allowing discrimination of the Area 8 plume from the Area 7 plume located a short distance to the south. While this plume has not impacted areas where drinking water wells are present, it is still a significant area of groundwater contamination.

The Area 9/10 contaminant plume has the third-highest concentrations of chlorinated VOCs in the study area. The plume also has a somewhat variable composition chemically: the upgradient portion has low ratios of TCE to TCA and high proportions of biodegradation daughter products, while two downgradient wells have high TCE/TCA and/or high PCE. It is not known whether these differences reflect variability within the same plume, or if two separate plumes are present.

It is likely that the Area 9/10 plume signals the presence of contaminant source(s) a short distance upgradient (probably near the southern boundary between Areas 9 and 10), based on the abundance of PCE and total chlorinated VOCs relative to wells just upgradient. The presence of a high proportion of degradation daughter products in this plume is most likely due to the presence of high concentrations of aromatic compounds (toluene and xylene) that have apparently fostered biodegradation. The downgradient extent of this plume has not been established.

The Area 4 contaminant plume is considerably smaller than those discussed above. This plume has a distinctive contaminant fingerprint based on the fact that TCA constitutes about 95% of total detected VOCs. The high-TCA fingerprint is observed in both soil gas and subsurface soil samples in and adjacent to Area 4. The correspondence of sampling results from various media suggests that the Area 4 plume derives from a single source located in the upgradient portion of Area 4. This plume crosses an area where water mains were extended and residents were provided City water in 1990. The Area 4 plume is located hydraulically upgradient of the Area 11 plume.

The Area 11 contaminant plume consists primarily of aromatic compounds (toluene, xylene, and ethylbenzene), though elevated concentrations (up to 2,900 ppb) of several chlorinated VOCs are known to be present. The plume of chlorinated VOCs can not be defined adequately at this time due to the problem of elevated detection limits. It is possible that chlorinated VOCs are present below the detection limits but were masked by the high concentrations of ETX compounds.

Furthermore, groundwater impacts at Area 11 from upgradient plumes cannot be evaluated because of the masking effect caused by the aromatic compounds.

Of the other contaminated areas at the site, the Area 15 and Area 19 plumes contain relatively low (less than 300 ppb total VOCs) contaminant concentrations; these plumes also do not appear to be very long. The Area 15 plume does not extend into the primary area of concern. The Area 19 plume is contained in the primary area of concern.

The Area 16, Area 17 and Area 18 plumes also contain low contaminant concentrations; however, the lateral and longitudinal extents of these plumes are not known. No source areas have been identified for these plumes at this time.

Higher VOC concentrations (both chlorinated and non-chlorinated) are present in the Area 13 plume; however, the extent of this plume is also unknown.

There are scattered areas with elevated contaminant concentrations in groundwater. These occurrences of low-concentration VOCs (<100 ppb) in areas with no known source could have been locations of disposal not previously identified. The fact that this possibility exists indicates that plumes should not yet be connected on the basis of low-concentration hits only. For example, the Area 8 and Area 7 plumes should not be connected based on low concentrations found in MW122A. The contaminant fingerprint at that well is more characteristic of Area 7 plume, and other Area 7-type contamination could very easily exist outside the limited zones that were surveyed for soil gas. The geophysical and soil gas work was not all-encompassing, and probably did not define the full extent of contamination in Area 7. Recent reports indicate that waste piles are present north of the area investigated but south of the railroad tracks. The contamination detected at MW122A may be the result of that disposal area.

The general distribution patterns of total halogenated VOCs in groundwater from the Operable Unit (1990), Phase I (1991), and Phase II (1993) are similar. The Phase II distribution delineates the primary area of concern. The Phase I and Phase II groundwater data are generally in good agreement; however, a significant concentration difference between Phase I and Phase II was observed at MW101B. DNAPL was not identified during the Phase II investigation.

Contaminant Source Evaluation

Based on the 104E information and the downgradient groundwater data, Gordon-Bartels does not appear to be a source of chlorinated VOCs in groundwater; however, low concentrations of ETX compounds were detected in groundwater immediately downgradient of the facility. It is likely this is a localized impact to the groundwater as these compounds do not persist very far downgradient.

Based on the soil gas information, potential source Areas 5 and 6 do not appear to be near-surface sources of VOCs.

Based on soil gas, soil boring and local groundwater flow and analytical data, potential source Area 12 is a near-surface source of VOCs and a potential local groundwater contamination source; existing data are not sufficient to determine contribution to the primary area of concern.

Based on previous studies that indicated high concentrations of VOCs beneath the building at Acme Solvents, Phase II soil gas and local groundwater flow and analytical data, potential source Area 13 is a near-surface source of VOCs and a local groundwater contamination source. Existing data are not sufficient to determine contribution to the primary area of concern.

Based on the groundwater analytical data and the hydrogeologic information, it appears that groundwater contamination originating from potential source Area 8 has a different contaminant fingerprint than the fingerprint of the groundwater contamination extending from Area 7 westward to Eleventh Street.

Based on groundwater, geophysical surveys, soil gas, and subsurface soil data collected during the Phase I and Phase II studies, source Area 7 is a significant near-surface source of VOC contamination and is contributing to groundwater contamination in the primary area of concern.

Based on soil gas, soil borings and groundwater data, Source Area 4 is a significant near-surface source of VOC contamination and is contributing to groundwater contamination in the primary area of concern.

Based on groundwater data, the Erhardt-Leimer facility has a small groundwater contaminant plume (Area 15 plume) that has not reached the area of concern located downgradient. This facility is still considered a source of groundwater contamination.

Source Area 11 is characterized by high concentrations of ETX, especially at the water table, indicating a likely the potential for residual LNAPL contamination. An additional issue in this area is that due to the high concentrations of the ETX compounds, analytical detection limits were raised and it is unknown if chlorinated VOCs are present at lower concentrations. The groundwater data downgradient does not indicate any major spikes that could be attributed to Area 11; however, the area could still be contributing chlorinated VOCs at lower concentrations.

The groundwater data downgradient from Areas 9 and 10 suggest possible contaminant source(s) near the boundary between these areas. Due to limited access in portions of these areas, no specific near-surface sources of VOCs were identified.

Based on soil gas, soil borings and groundwater data, Area 14 does not appear to be a current source of near-surface VOC contamination. Based on the previous existence of high contaminant concentrations in soils that were removed from the site in about 1989, it is likely that the site was at one time a source of contamination. However, in the areas investigated, there is little current evidence of past problems, based on a lack of contaminant spikes in groundwater roughly downgradient.

Based on soil gas information, Areas 1 and 3 do not appear to be current, significant near-surface sources of VOC contamination. The source of the PCE in the nearby residential wells was not determined; however, the dry cleaner does not appear to be a source.

Based on soil gas and soil boring information, Area 2 may be a current minor near-surface source of VOCs for the study area. Previous effects from this area may have been more significant. Water mains were extended and residents were provided with City water within Area 2 in 1990.

Groundwater Modeling

Groundwater flow and contaminant transport modeling was done using three-dimensional, numerical models developed by Camp Dresser & McKee Inc. These codes use the finite element method to model groundwater flow, and the random walk method to simulate the transport of dissolved organic compounds. Historical groundwater flow fields were simulated for the time period encompassing the likely period of active contamination at the site.

The calibrated groundwater flow model produced good agreement between simulated and measured heads using appropriate hydraulic parameters for the stratigraphic units represented in the model. Groundwater elevations from over 100 monitoring wells were used in the calibrated flow model. The simulated horizontal and vertical hydraulic gradients agree reasonably well with the observed gradients.

Pumping at the City of Rockford's municipal wells produces drawdown in the deep bedrock aquifers. These cones of depression were reasonably reproduced in the model by incorporating pumping data from the City's unit wells. Flow simulation results indicate that deep pumping west of the Rock River is capable of capturing a portion of the groundwater from east of the river in the St. Peter Sandstone and overlying Valley Deposits.

The contaminant transport model was found to reasonably represent the horizontal and vertical distribution of contaminants in the study area using appropriate transport parameters, source locations, and contaminant loading rates. The historical groundwater flow fields were used to implement contaminant transport simulations of 1,1,1-TCA and 1,1-DCA for the time period 1955 to the present.

Contaminant transport simulations for five major source areas (Areas 4, 7, 8, 9/10, and 14) located within the study area demonstrate the predictive capacity of the calibrated transport model to reasonably reproduce the observed TCA-DCA contaminant distribution.

Risk Assessment

Thirteen of the twenty-four residential wells have a total carcinogenic risk within the $1E-04$ to $1E-06$ risk range defined by the USEPA. No homes have a total carcinogenic risk meeting or exceeding the upper limit of the EPA's target range, which is $1E-04$.

The four residential wells with the highest total carcinogenic risk numbers are located at 1726 (and 1730) Pershing, 1713 Harrison and the two wells at 2131 Harrison. The two wells at 2131 Harrison serve 25 trailers in the trailer park.

Hazard indices for each household are all below 1, indicating that non-cancerous or toxic human health effects from exposure to the groundwater at these residences is unlikely.

The MCL for TCE is exceeded at the two residential wells at 2131 Harrison. The MCL only considers health effects resulting from ingestion of contaminated water, and therefore may not be protective if additional chemical exposure occurs through other routes. Therefore, the MCLs cannot be used to assume that water from other residences, where MCLs are not exceeded, will not impact human health.

The groundwater modeling future plume scenarios indicate the possibility that the groundwater plume may move to encompass additional homes within the study area within the next 70 years.

Chemical concentrations detected in the residential wells were lower than concentrations detected in the monitoring wells within the main plume area. Because estimates of hazard index and risk are directly proportional to chemical concentration, should the wells within the main plume be used for drinking and associated household water uses, hazard indices and risks associated with these wells would be higher than those estimated in the risk assessment for the wells outside of the plume.

Chemical concentrations detected in residential wells as part of the operable unit investigation were generally higher than concentrations detected during the Phase II assessment; therefore, those wells would have higher associated hazard indices and risk estimates. It is important to note that several of the residential wells sampled during the OU which were found to exceed Maximum Contaminant Levels were south of the presently defined main plume. These wells, and abutting wells have been hooked up to public water.

7.2 Recommendations

No further investigation is needed at Gordon Bartels or Erhardt-Leimer to support the groundwater feasibility study (FS), however it is recommended that response actions be conducted to mitigate their groundwater contamination.

No further study is necessary at Area 8 to support the groundwater feasibility study. However, it is recommended that additional work be conducted to evaluate the effectiveness of the groundwater recovery system and extent of any near surface sources.

Despite the fact that the data were not conclusive enough to determine contributions to the area of concern, no further study is necessary for Areas 12 and 13 to support the groundwater feasibility study; however, since it is documented that releases have occurred, these facilities should be remediated.

Additional source delineation work is recommended in the northern portion of Area 7, where the full limits of contamination were not defined. Soil borings and soil gas should be performed as part of future source studies.

A modified soil gas study should be performed near the residences west of Area 7 to allow an evaluation of the VOC concentrations in the soil gas versus concentrations in the ambient air.

Additional investigation is recommended for the facilities in Area 11 to determine the source of the ETX contamination to further evaluate if a surficial source of chlorinated VOCs is present. Source characterization work such as soil gas and soil borings are recommended, particularly around the tank area where access was not obtained in Phase II. Facility inspections and disposal histories should also be prepared.

Further investigations of portions of Areas 9 and 10 where access was not obtained are recommended. Initial investigation should include information requests and facility surveys, both visual and soil gas to characterize possible source area(s) associated with the 9/10 plume.

In the areas where NAPL contamination is suspected (4, 7, 11, and 12), future source investigations should include an evaluation of the potential NAPL contamination per the USEPA guidance on DNAPL site characterization. This will require a phased investigation approach beginning with development of a conceptual model followed by specific investigation activities designed to minimize the risk of spreading any NAPL zones.

For Areas 4 and 7, the most significant near-surface source areas investigated near the residential hook-up area, treatability studies are recommended. Studies should include soil vapor extraction, bio-enhanced soil vapor extraction, air sparging and/or in-situ bioremediation. These studies should be conducted prior to the source area feasibility study(s).

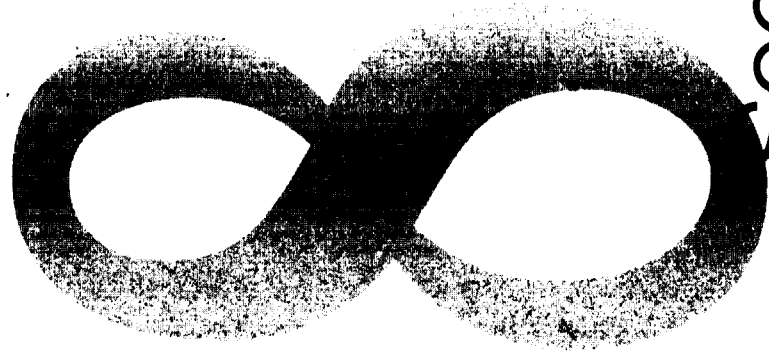
Evaluate the effect of pumping at UW35 on plume movement using existing information and, if necessary, a pump test.

Based on the level of risk currently associated with the wells located at 1726 and 1730 Pershing, 1713 Harrison and 2131 Harrison, and the potential for future plume movement into these areas, it is recommended that these residents be provided with an alternate water supply. Final evaluation of the number of residents provided with an alternate water supply will be determined in the feasibility study.

Due to the uncertainty in predicting plume movement and future concentrations, it is recommended that an "early warning" monitoring system be put into place to evaluate actual plume movement towards residential wells where an alternate water supply is not provided.

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Section 8



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Section 8 References

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